CROSS CANYON - SQUAW/PAPOOSE CANYONS - CAHONE CANYON AREA

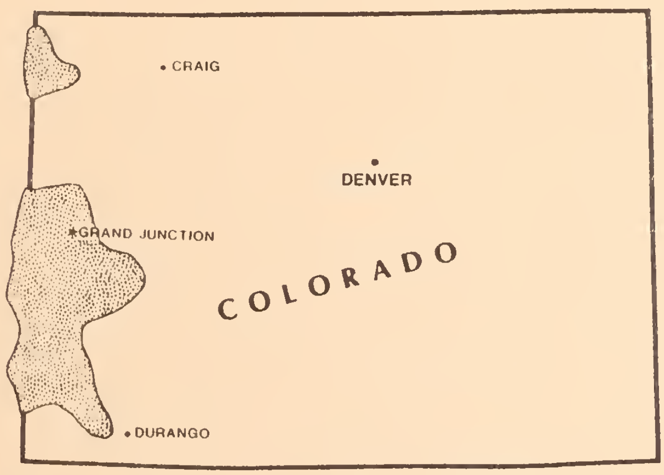
GEOLOGICAL RESOURCE AREA (GRA) 10

FINAL REPORT

PHASE 1: GEM

(GEOLOGICAL, ENERGY and MINERALS)

RESOURCE ASSESSMENT FOR REGION 4, COLORADO PLATEAU



SUBMITTED TO:
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
DENVER SERVICE CENTER
DENVER, COLORADO 80225

MSME/WALLABY ENTERPRISES
A JOINT VENTURE OF
MOUNTAIN STATES MINERAL ENTERPRISES, INC.
and WALLABY ENTERPRISES, INC.

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TABLE OF CONTENTS

FOREWORD

This report is one of a series of eleven reports addressing the Wilderness Study Areas (WSA's) located in what has been designated as the Colorado Plateau, Region 4, by the Bureau of Land Management (BLM), Denver Federal Center. The study was under the direction of Mr. Robert J. Coker, the Contracting Officer's Authorized Representative (COAR).

The WSA's have been segregated into eleven G-E-M (Geology, Energy, Minerals) Resources Areas (GRA's). Each designated GRA constitutes one report. The purpose of these reports is to assess the potential for geology, energy and mineral (GEM) resources existing within a WSA and GRA. This information will then be used by BLM geologists in completing the assessment for GEM resources potential within the WSA's, and for the integration with other resource data for the decision on suitability for recommendation of the respective WSA.

The reports were developed and prepared by the Joint Venture team of MSME/Wallaby Enterprises, Tucson, Arizona, by Patricia J. Popp (Geologist), and Barbara J. Howie (Geologist) under the direction of Eric A. Nordhausen (Project Manager) and Richard Lundin (Principal Investigator), under BLM Contract No. YA-553-CT2-1041.

Consulting support was provided by a highly specialized geological team composed of: Ted Eyde, Dr. Paul Gilmour, Dr. Robert Carpenter, Dr. Donald Gentry, Dr. Edger Heylmun, Dr. Larry Lepley, Annon Cook, Walter Heinrichs, Jr., and Charles Campbell. Their contribution is both acknowledged and appreciated. The work of Dr. Gilmour, Mr. Cook, and Dr. Lepley should receive special acknowledgement. It was from the work of these consultants that this report on the Cross Canyon - Squaw/Papoose Canyons - Cahone GRA was able to be completed.

EXECUTIVE SUMMARY

The BLM has adopted a two-phase procedure for the integration of geological, energy and minerals (GEM) resources data for suitable/nonsuitable decisions for wilderness study areas (WSA's). The two-phased approach permits termination of a GEM resources data gathering effort at the end of Phase One. The objective of this Phase One GEM resources assessment is the evaluation of existing data (both published and available unpublished data) and their interpretation for the GEM resources potential of the WSA's included in each region. Phase Two is designed to generate new data needed to support GEM resources recommendations.

Over 10 million acres of WSA's require GEM resources data input. These WSA's are unequally distributed in the eleven western states of the coterminous United States. The WSA's are grouped in six regional areas. The WSA's within the western part of Colorado, and a few crossing into Utah, were included as Region 4, also known as the Colorado Plateau Region. Except for one small area at the southwest extreme of the region and another at the north extreme, the region is within the northern half of the known Colorado Plateau physiographic province.

The 32 WSA's within Region 4 encompass 474,620 acres. These have been geographically segregated within 11 designated GEM Resource Areas (GRA's). This report addresses the Cross Canyon-Squaw/Papoose Canyons-Cahone Canyon area, GRA 10. Included in the GRA is Cross Canyon WSA (CO-030-265 and UT-060-229), Squaw/Papoose Canyons WSA (CO-030-265A and UT-060-227), and Cahone Canyon WSA (CO-030-265D).

The physiography of the GRA includes canyons with projecting erosion remnants and irregular topography. All the rock units are sedimentary, representing portions of Mesozoic time. Faults, shear zones and joint system interact to control the course of drainage systems, and well as help localize oil and gas.

The energy and mineral resources include oil, gas, helium, coal, uranium and vanadium, copper, silver, construction stone, and sand and gravel. The GRA includes five major gas and oilfields (Bug, Dove Creek, Papoose Canyon, Squaw Canyon, and Patterson) that produce from a stratigraphic trap in Pennsylvanian units. Coal deposits occur in Cretaceous Formations. Uranium and vanadium deposits occur as secondary mineralization in Jurassic units. Copper and silver were produced from the Mesozoic section (specific information was not available). Construction stone was produced from a Cretaceous unit. Sand and gravel were deposited along the tributary systems in the canyons in the GRA.

The classification for the leasable minerals, locatable and salable resources varies. All three WSA's have a high favorability for leasable resources in the form of oil, gas, carbon dioxide and helium; and a moderate to high favorability for coal, gypsum and salts, and brines and potash. There is an unknown potential, due to lack of published literature and geologic field investigations, for locatable minerals in all three WSA's. High favorability for salable resources exists in each of the WSA's in the form of dimension stone, structural and bentonite clays, and limestone.

Overall, it is recommended that each WSA in the GRA receive additional work to determine the full economic potential of each area. This work should include further research in the unpublished and proprietary literature, a detailed program of geologic mapping and sampling, and additional geochemical and stratigraphic studies.

SECTION I

INTRODUCTION

The Cross Canyon-Squaw/Papoose Canyons-Cahone Canyon GRA (Figure I-1) is located in Montezuma and Dolores Counties, Colorado, and San Juan County, Utah. The GRA encompasses three Wilderness Study Areas (WSA's); Cross Canyon (CO-030-265 and UT-060-229) Squaw/Papoose Canyons (CO-030-265A and UT-060-227) and Cahone Canyon (CO-030-265D).

The GRA area is located approximately 20 miles northwest of Cortez, Colorado. Located within the GRA are a number of small settlements that are local supply centers for agriculture and ranching activities. These towns of Dove Creek, Cahone, Pleasant View, Northdale, Eastland, and Lockerby, are supplied over road networks from Grand Junction and Cortez, Colorado, the regional supply centers. The towns are also local supply centers for the oil, gas and mineral operations in the area.

The area in Colorado includes portions of Townships 37-41 North, Ranges 17-20 West; and Townships 34-38 South, Ranges 24-26 East in San Juan County Utah. The entire area is bounded by west longitudes 108° 44' 31" to 109° 12' 26" and north latitudes 37° 26' 11" to 37° 49' 04". It contains approximately 655 square miles (1,760 square kilometers or 419,000 acres) of federal, state and private lands. The Bureau of Land Management portion of these holdings are under the jurisdiction of the Colorado Montrose District Office and San Juan Resource Area Office, and the Utah Moab District Office.

The specific WSA's within the GRA have a total of 29,085 acres of federal land. The acreages of the various contained WSA's are:

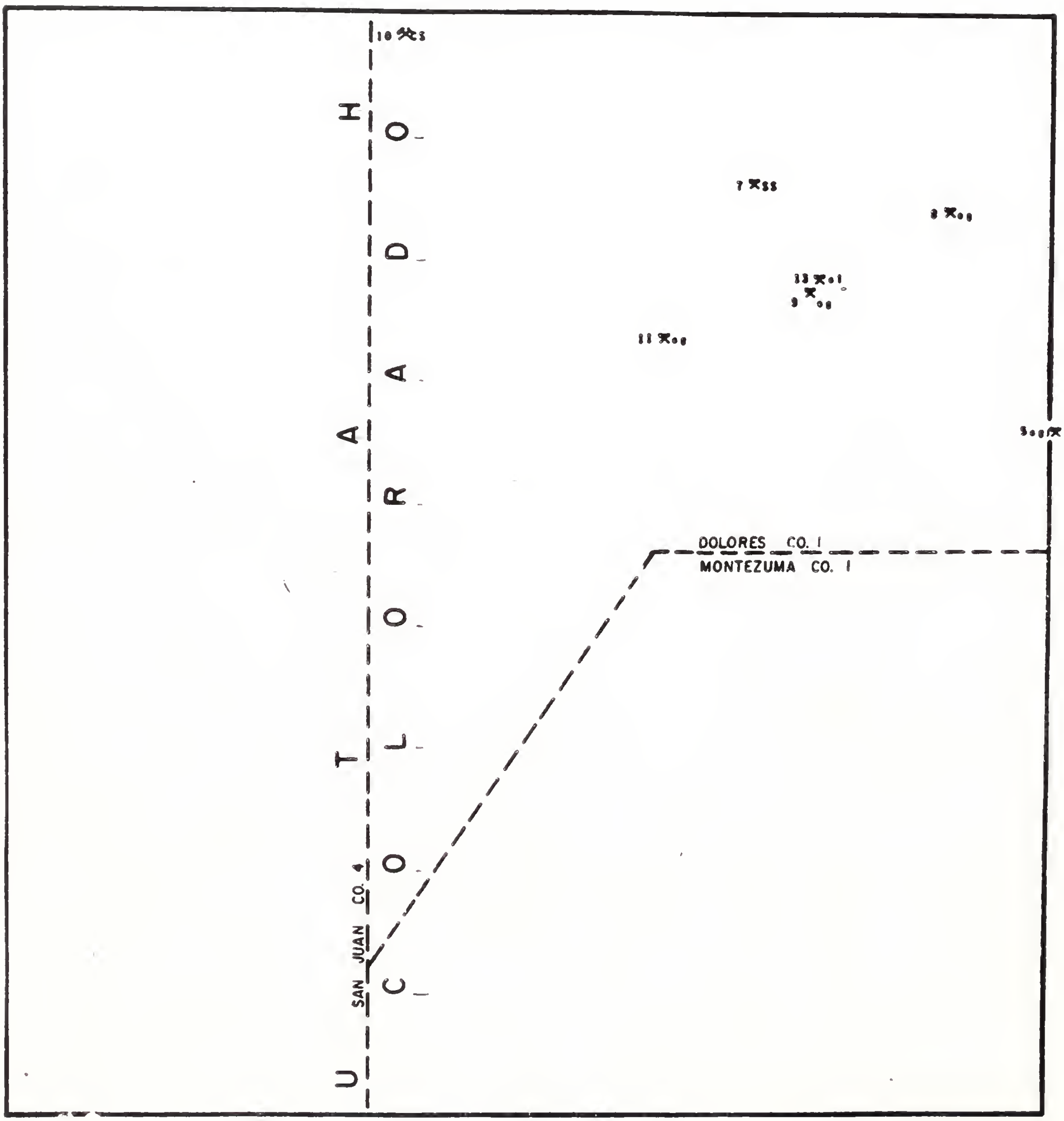
Cross Canyon (CO-030-265 & UT-060-229) - 9,440 acres
Squaw/Papoose Canyons (CO-030-265A & UT-060-227) - 11,260 acres
Cahone Canyon (CO-030-265D) - 8,385 acres

The Cross Canyon WSA is located in the south-central part of the GRA and is approximately 14 miles southwest of Cahone, Colorado. The Squaw/Papoose Canyon WSA is located directly north of the Cross Canyon area, and is 12 miles southwest of Dove Creek, Colorado. The Cahone Canyon WSA is in the northeast portion of the GRA and lies 3 miles west of Cahone, Colorado. All of the WSA's lie approximately 25 miles northwest of Cortez, Colorado, a regional urban and supply center.

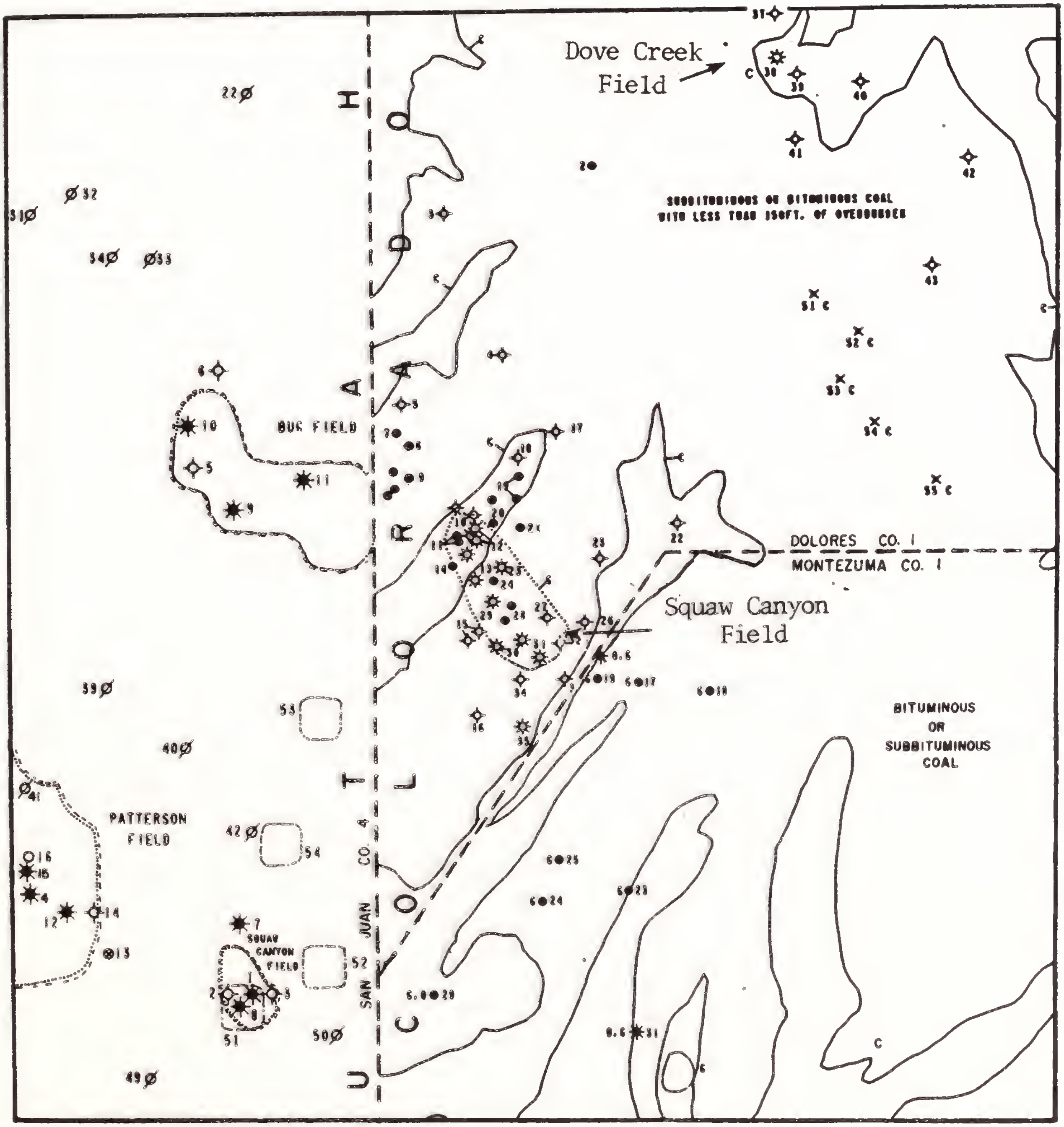
Due to the lack of available data on each WSA, emphasis was placed on gaining an understanding of the mineral potential of each WSA within the GRA. Information on the mineral resources of GRA was utilized to extrapolate and estimate the potentials of the contained WSA's from the existing data that in most cases, referred only indirectly to the WSA's. The purpose of this contract was to utilize the known geological information within each WSA and GRA to ascertain the GEM resource potential of the WSA's. The known areas of mineralization and claims have been plotted as overlays to Figure I-1.

The information contained in this report was obtained from published literature, computerized data base sources, Bureau of Land Management File Data, company files and returned data sheets. The information was compiled into a series of files on each WSA and a series of maps that covered the entire western portion of Colorado. After a thorough review of the existing data, a program of field checking was carried out by MSME/Wallaby's team of experts. Field investigations in the GRA were carried out by Dr. Paul Gilmour, and Mr. Annan Cook during the period of August 31 - September 1, 1982.

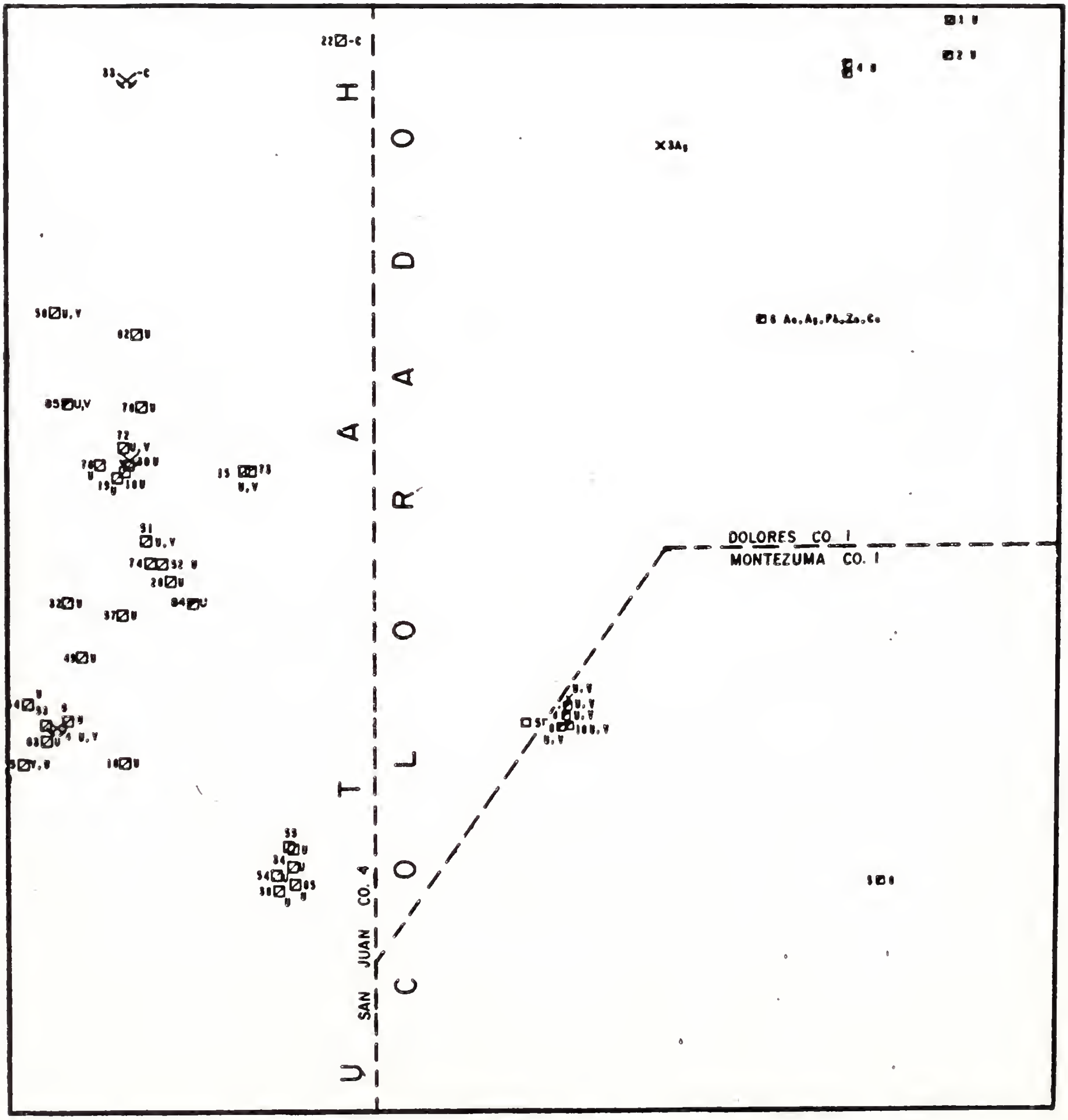
All of these individuals are registered professional geologists and associates of MSME/Wallaby. Further analysis and study was provided through the photographic interpretation services of BLM 1:24,000 aerial photos by Dr. Larry Lepley, registered professional geologist and remote sensing specialist. The aerial photos used are included in Appendix A.



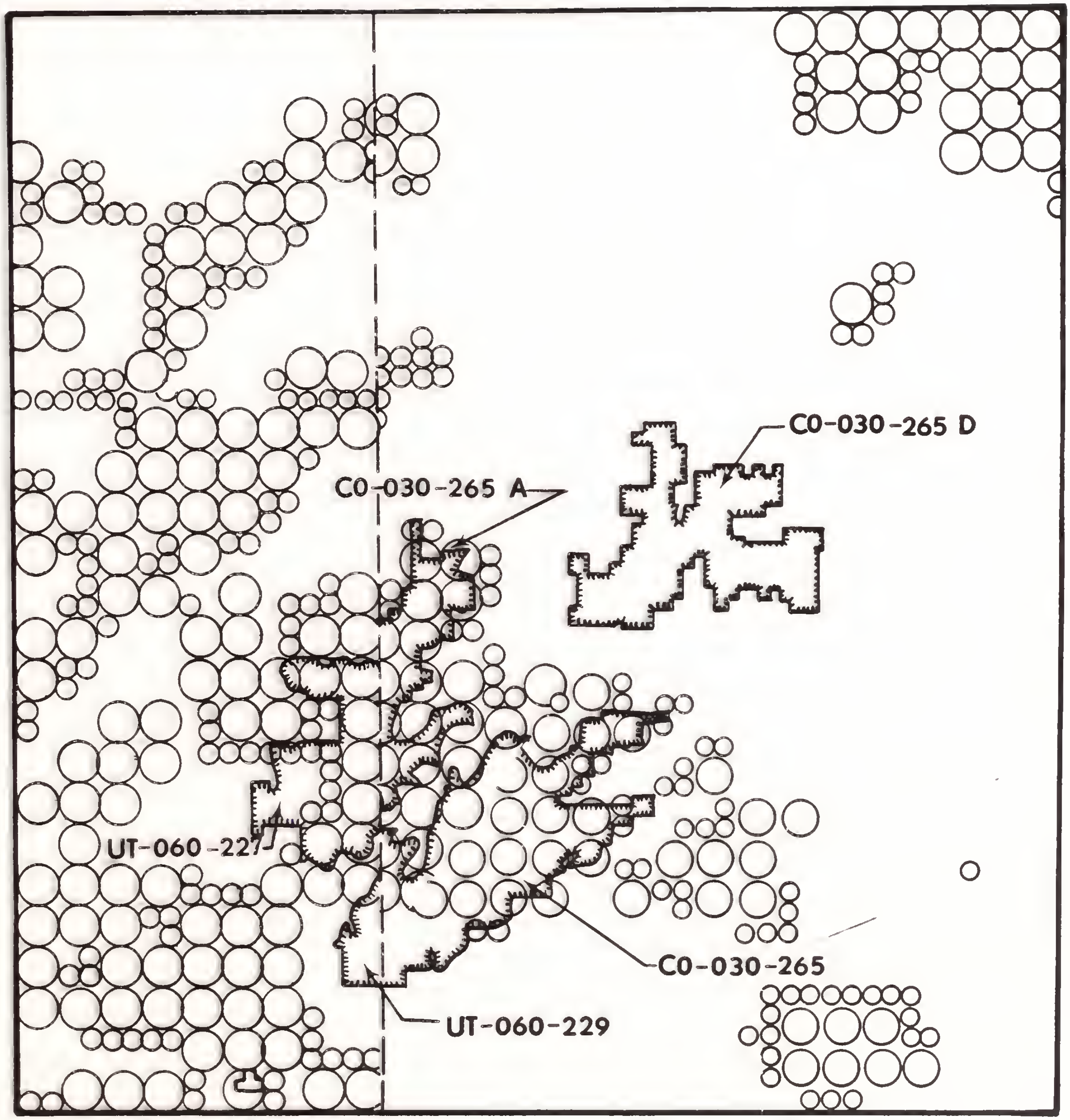
OVERLAY D:
SAND, GRAVEL AND
INDUSTRIAL MINERALS



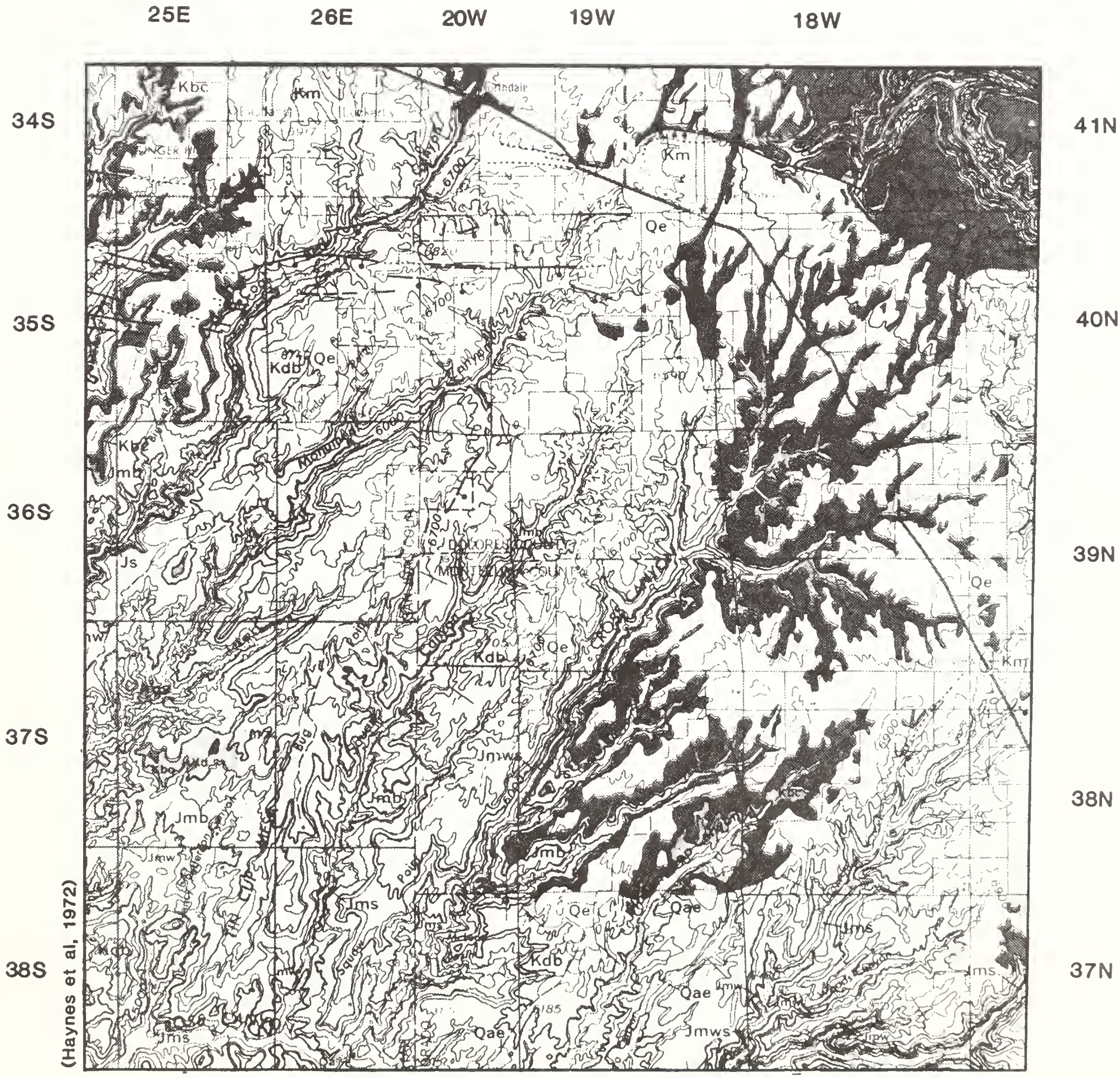
OVERLAY C:
COAL, OIL AND GAS



OVERLAY B:
MINES, PROSPECTS
AND MINERAL OCCURENCES



OVERLAY A:
PATENTED AND UNPATENTED
CLAIMS AND WSA BOUNDARIES



CROSS CANYON/SQUAW/PAPOOSE CANYONS/CAHONE CANYON GRA

N

SCALE 1:250,000

FIGURE I-1
GEOLOGIC MAP

EXPLANATION

Quaternary (Approximately 2 million years before present (mybp) to present)	Qae	Alluvial and eolian deposits
	Qa	Alluvium deposits
	Qap	Pediment gravels
	Qc	Colluvial deposits
	Qct	Talus
	Qcl	Landslide deposits
	Qat	Terrace gravels
Cretaceous (Approximately 135-62 mybp)	Kmvg	Mesaverde Group
	Kmvu	Upper part of Mesaverde Group
	Kc	Castlegate Sandstone
	Kb	Upper member of Blackhawk Formation
	Kmv	Mesaverde Formation
	Kmvr	Mesaverde Formation, Rollins Sandstone Member
	Kmb	Buck Tongue of the Mancos Shale
	Km	Mancos Shale, undifferentiated
	Kmu	Mancos Shale, upper shale Member
	Kmfe	Mancos Shale, Ferron Sandstone Member
	Kml	Mancos Shale, lower shale Member
	Kd	Dakota Sandstone
	Kbc	Burro Canyon Formation
	Kdb	Dakota Sandstone and Burro Canyon Formation
	Kmdb	Mancos Shale, Dakota Sandstone, and Burro Canyon Formation
Jurassic (Approximately 195-135 mybp)	Jml	Morrison Formation
	Jmb	Morrison Formation, Brushy Basin Shale Member
	Jms	Morrison Formation, Salt Wash Sandstone Member
	Js	Summerville Formation
	Jem	Entrada Sandstone, Moab Sandstone Member
	Je	Entrada Sandstone
	Jsem	Summerville Formation and Moab Sandstone Member of Entrada Sandstone
	Jse	Summerville Formation and Entrada Sandstone
	Jwe	Wanakah Formation and Entrada Sandstone
Jurassic and Triassic	J Tr sen	Summerville Formation, Entrada Sandstone, and Navajo Sandstone
	J Tr n	Navajo Sandstone
	J Tr gc	Glen Canyon Group - Navajo Sandstone, Kayenta Formation and Wingate Sandstone
Triassic (Approximately 225-195 mybp)	Trk	Kayenta Formation
	Trw	Wingate Sandstone
	Trkw	Kayenta Formation and Wingate Sandstone
	Trd	Dolores Formation
	Trwc	Wingate Sandstone and Chinle Formation
	Trc	Chinle Formation, undifferentiated
	Trcu	Upper part of Chinle Formation
	Trcb	Chinle Formation, Moss Back Member

Triassic continued	Trcm	Chinle and Moenkopi Formations
	Trm	Moenkopi Formation
Permian (Approximately 280-255 mybp)	Pe	Cutler Formation, undifferentiated
	Pca	Cutler Formation, arkose and arkosic conglomerate
	Pcw	Cutler Formation, White Rim Sandstone Member
	Pco	Cutler Formation, Organ Rock Tongue
	Pcc	Culter Formation, Cedar Mesa Sandstone Member
	Pcwo	Cutler Formation, White Rim Sandstone Member and Organ Rock Tongue
	Pcac	Cutler Formation, Transition zone, arkosic beds and Cedar Mesa Sandstone Member
Permian & Pennsylvanian	P Pr	Rico Formation
	P Pcr	Cutler and Rico Formations
Pennsylvanian (Approximately 320-280 mybp)	Ph	Hermosa Formation, undifferentiated
	Phu	Upper Member
	Php	Paradox Member
Precambrian (Approximately 3400-600 mybp)	pC	Precambrian rocks, undifferentiated

LEGEND

-O OIL FIELD

-G GAS FIELD

-Os OIL SHALE

-C COAL REGION

OIL WELL

OIL & GAS WELL

GAS WELL

SHOW OF GAS

SHOW OF OIL

SHOW OF OIL & GAS

-C COAL DEPOSIT

-C COAL OCCURRENCE

SHUT-IN WELL

CO_2 OR He=HELIUM -RICH WELL

DRY WELL-ABANDONED

MILL

PLANT

NATURAL GAS PROCESSING PLANT

REFINERY

MINERAL OREBODY

MINERAL DEPOSIT

MINERAL OCCURRENCE

PROSPECT

ACCESSIBLE ADIT

INACCESSIBLE ADIT

VERTICAL SHAFT

INCLINED SHAFT

MINE TYPE UNKNOWN

ACTIVE OPEN PIT, OR QUARRY

INACTIVE OPEN PIT, OR QUARRY

ACTIVE GRAVEL OR CLAY (Cl) PIT

INACTIVE GRAVEL OR CLAY (Cl) PIT

EXPLORATION HOLE WITH DATA AVAILABLE

EXPLORATION HOLE WITHOUT DATA AVAILABLE

UNPATENTED MINING CLAIM

PATENTED MINING CLAIM

MINERAL OR OIL & GAS LEASE

O	OIL
G	GAS
Os	OIL SHALE
Ot	TAR SANDS
Gi	GILSONITE
C	COAL
Cb	LIGNITE
Cp	PEAT
Ag	SILVER
Au	GOLD
Cu	COPPER
Cl	CLAY
Ds	DIMENSION STONE
Fe	IRON
Mn	MANGANESE
Pb	LEAD
U	URANIUM
V	VANADIUM
Zn	ZINC

SECTION II

GEOLOGY

PHYSIOGRAPHY

Within the GRA boundary are numerous northeast trending canyons that cut uplifted sedimentary beds and exposed resistant rock units along the canyon walls. Projecting erosion remnants, and the irregular canyon topography, give the canyon bottom a rugged character. Talus slopes along the walls of the canyons are steep-sided. The major canyon systems of the GRA (Cross, Squaw, Papoose, Cahone, Monument and Coal), cut and dissect an area of relatively flat terrain. While the vertical relief in the canyons is approximately 1,500 feet, the plateau areas around the towns of Cahone, Dove Creek and Pleasant View have only a few hills that rise above 500 feet. All of the northeast trending canyon systems within the GRA eventually drain into the Cross Canyon-San Juan River drainage. The Big Canyon drainage northeast of Dove Creek, Colorado drains into the Dolores River Canyon, and has a vertical relief of approximately 1,000 feet.

The following descriptions address the physiographic composition of each of the WSA's within the Cross Canyon-Squaw/Papoose Canyons-Cahone Canyon GRA.

CROSS CANYON WSA (CO-030-265 and UT-060-229)

The area consists of portions of several canyons, including Cross, Ruin and Cow Canyons, that have been formed by fluvial erosion of a series of uplifted sedimentary beds.

Numerous rock outcrops, ledges, and cliffs are exposed in the canyons. The canyons range in depth from 300 feet to 900 feet. In addition to the main canyons, there are numerous smaller tributary canyons that form a network of ravines and pinnacles in some areas. Vertical relief in the WSA is approximately 1,000 feet. The WSA is located 20 miles northwest of Cortez, Colorado.

SQUAW/PAPOOSE CANYONS WSA (CO-030-265A and UT-060-227)

This area consists primarily of two canyons (Squaw and Papoose) that have been cut by fluvial erosion into an uplifted section of the Jurassic Morrison Formation and Cretaceous Dakota Sandstone. The canyon slopes are composed of exposed rock outcrops and steep talus slopes. Numerous tributary canyons merge into the main canyon systems and form a network of ravines and rocky outcrops. Vertical relief in the area is approximately 1,000 feet. The WSA is located approximately 31 miles northwest of Cortez, Colorado.

CAHONE CANYON WSA (CO-030-265D)

The dominating feature of this area is the confluence of three deep canyons (Cross, Cahone, and Dove Creek), that have been cut by the fluvial erosion of the Morrison Formation and Dakota Sandstone. The steep canyon walls consist of numerous rock outcrops, talus slopes and areas of shallow, rocky soils.

Sandstone cliffs and ledges line the canyon rims. Vertical relief in the area is approximately 500 feet. The WSA is located approximately 25 miles northwest of Cortez, Colorado.

ROCK UNITS

Within the Cross Canyon-Squaw/Papoose Canyons-Cahone Canyon GRA is found a variety of rock units that represents portions of Mesozoic time. The pre-Jurassic section is not exposed within the boundaries of the GRA but is thought to exist at depth (Baars et al, 1981). Some of these units have been extensively studied by oil and gas companies. Of particular interest is the Pennsylvanian Hermosa Formation and it's Paradox Member. These units are thought to underlie most of the GRA, as the GRA is located within the Paradox Structural Basin which was receiving sediments from the Precambrian through Permian periods (Molenaar, 1981; Baars et al, 1981).

During the Triassic Period, the Chinle, Wingate, and Kayenta Formations were deposited in the area of the GRA (Molenaar, 1981; Baars et al, 1981). From the drilling and geophysical information, it is thought that the Chinle was deposited directly upon a Permian erosion surface over much of the GRA (Molenaar, 1981; Baars et al, 1981). It is also thought that the Triassic-Jurassic Navajo Sandstone Formation was not deposited in the area of the GRA (Molenaar, 1981; Baars et al 1981; Heylmun, Personal Communication, 1982).

Directly and unconformably above the Triassic units are the Jurassic Entrada Sandstone, Wanakah, and Morrison Formations. These units crop out within the the GRA, and have been well studied for uranium, vanadium, and oil and gas resources by both the Federal government and industry (Baars et al, 1981; Carter et al, 1965; Heylmun, Personal Communication, 1982).

Within the GRA, the Entrada Sandstone is known only from drilling information and isolated outcrops in the northeast portion of the GRA (Haynes et al, 1972; Molenaar, 1981). The Entrada Sandstone consists of three members (in ascending order: Dewey Bridge, Slick Rock and Moab). The Dewey Bridge Member of the Entrada is characterized as a series of sandy siltstones and sandstones with a clastic conglomerate unit at the base (Molenaar, 1981). This unit is considered to have been deposited in a shallow-marine environment that was adjacent to a major ocean basin or seaway (Molenaar, 1981). The Slick Rock Member is a sandstone unit that grades into a silty sandstone west of the Paradox Basin. The unit is thought to be of eolian origin and exhibits prominent cross-bedded structures. The Moab Member of the Entrada is very similar in appearance to the Slick Rock Member, but is thought to have been deposited in a coastal dune environment (Molenaar, 1981).

In other areas of the Paradox Basin, the Entrada Formation is unconformably overlain by the Jurassic Curtis Formation, a glauconitic marine sandstone. Within the GRA the Curtis does not outcrop and may have as an equivalent the Summerville Formation (Molenaar, 1981). The Summerville Formation is thought to directly overlie the Entrada wihtin the GRA and consists of a series of mudstone, sandstone, and shale units with occasional masses and beds of chert. The Summerville is interpreted as a marginal marine, tidal flat deposit (Molenaar, 1981; Baars et al, 1981; Haynes et al, 1972; Carter et al, 1965).

The Jurassic Wanakah Formation has been mapped as a separate unit from the Summerville in much of southwestern Colorado and consists of three distinct members in the Silverton area (Molenaar, 1981).

Within the Paradox Basin area of Utah, the Wanakah units lose their distinction from those of the Summerville Formation and have been mapped together with the Summerville (Molenaar, 1981). Within the GRA, the Wanakah is comprised of a series of mudstone, cherty algal limestone, gypsiferous mudstone, sandstone, and limestone units (Tweto et al, 1976; Haynes et al, 1972). Due to stratigraphic intertonguing, the Wanakah and Morrison Formation units are often mapped together (Haynes et al, 1972).

The Upper Jurassic Morrison Formation generally overlies the Wanakah Formation and consists of a series of units that comprise four distinct and separate members in the southern portion of the Paradox Basin. The units thought to outcrop within the GRA are the Westwater Canyon and Brushy Basin Members. These units consist of a series of mudstone, shale, limestone and conglomerate beds. The Westwater Canyon Member is known only from a few outcrops in the southern portion of the GRA, and is known to pinch out in this area (Molenaar, 1981; Carter et al, 1965; Haynes et al, 1972).

Major uranium-vanadium deposits have been found in the Salt Wash Member of the Morrison in western Colorado (Molenaar, 1981; Carter et al, 1965; Vanderwilt, 1947). This unit may exist within the GRA but has not been specifically broken out in the existing and available geologic mapping (Haynes et al, 1972). In the Grants area of New Mexico, the Westwater Canyon Member of the Morrison is also known for uranium-vanadium deposits (Molenaar, 1981). The entire Jurassic section is known to contain uranium-vanadium deposits in various areas of Arizona, Colorado, New Mexico, and Utah. Local conditions and the occurrence of favorable stratigraphy determine the potential for economic deposits. A number of uranium-vanadium occurrences have been mined in the past within the GRA (Nelson-Moore et al, 1978). These occurrences are, for the most part, in the Salt Wash Member of the Morrison or the Summerville Formation, both of which are known for their uranium-vanadium deposits in the nearby Slick Rock District (Carter et al, 1965; Haynes et al, 1972).

Directly overlying the Jurassic stratigraphy, the Cretaceous Burro Canyon and Dakota Sandstone Formations consist of a series of fluvial sandstone, conglomerate, siltstone, shale, mudstone, and limestone units that have interbedded non-marine shale and coal units (Haynes et al, 1972). The Dakota Formation is known to contain minable coal resources in other areas of Colorado (Vanderwilt, 1947; Speltz, 1976). These units crop out throughout the GRA and are overlain by the Cretaceous Mancos Shale and Quaternary eolian material. The Mancos Shale Formation consists of a series of black fissle shale units with thin sandstone beds (Haynes et al, 1972). The Mancos Shale Formation outcrops as a series of resistant units that form topographic highs.

Quaternary eolian and alluvial material directly overlies much of the GRA and is found on Cretaceous erosion surfaces, as well as along the various drainages that cut through the Mesozoic section (Haynes et al, 1972).

The following descriptions address the rock units in each WSA in the Cross Canyon-Squaw/Papoose Canyons-Cahone Canyon GRA.

CROSS CANYON WSA (CO-030-265 and UT-060-229)

Within the boundaries of this WSA, the Jurassic Summerville and Morrison Formations crop out and are overlain by the Cretaceous Burro Canyon and Dakota Sandstone Formations, and by Quaternary eolian material.

The Jurassic Summerville Formation consists of a series of mudstone, siltstone, sandstone, and shale units with occasional masses of chert (Molenaar, 1981). The overlying Morrison Formation units are thought to consist of portions of the Salt Wash and Brushy Basin Members, and are reported to be a series of mudstone, shale and sandstone units with local conglomerate lenses (Cook, Personal Communication, 1982; Haynes et al, 1972). There are reported uranium-vanadium occurrences associated with these units in areas directly adjacent and north of the WSA (Nelson-Moore et al, 1978). Isolated occurrences of the Whitewater Canyon Member of the Morrison have been mapped in the same general vicinity as the reported occurrences, and may also be mineralized (Carpenter, Personal Communication, 1982; Cook, Personal Communication, 1982). Directly overlying the Morrison Formation is the Cretaceous Burro Canyon Formation. This unit consists of a series of fluvial sandstone, siltstone, shale and mudstone beds that locally have thin interbedded limestone units (Haynes et al, 1972). The Burro Canyon Formation is, in turn, directly overlain by the sandstone, shale and conglomerate units of the Dakota Sandstone. Within the WSA the Dakota is known to contain thin, discontinuous coal beds. These units have not been commercially exploited in the past and may have some economic potential for coal (Cook, Personal Communication, 1982; Gentry, Personal Communication, 1982).

The Cretaceous and Jurassic units are directly overlain by Quaternary eolian material. Similar age alluvium can be found along the various stream courses cutting through the WSA (Haynes et al, 1972).

SQUAW/PAPOOSE CANYONS WSA (CO-030-265A and UT-06-227)

Within the boundaries of this WSA, the Jurassic Summerville and Morrison Formations crop out and are overlain by the Cretaceous Burro Canyon Formation and Dakota Sandstone and by Quaternary eolian material. The Jurassic Summerville Formation consists of a series of mudstone, siltstone, sandstone, and shale units with occasional masses of chert (Molenaar, 1981). The overlying Morrison Formation units are thought to consist of portions of the Salt Wash and Brushy Basin Members, and are reported to be a series of mudstone, shale and sandstone units with local conglomerate lenses (Cook, Personal Communication, 1982; Haynes et al, 1972). There are reported uranium-vanadium occurrences associated with these units in areas directly adjacent and north of the WSA (Nelson-Moore et al, 1978).

Directly overlying the Morrison Formation is the Cretaceous Burro Canyon Formation. This unit consists of a series of fluvial sandstone, siltstone, shale and mudstone beds that locally, have thin interbedded limestone units (Haynes et al, 1972). The Burro Canyon Formation is, in turn, directly overlain by the sandstone, shale and conglomerate units of the Dakota Sandstone. Within the WSA, the Dakota is known to contain thin, discontinuous coal beds. These units have not been commercially exploited in the past and may have some economic potential (Cook, Personal Communication, 1982; Gentry, Personal Communication, 1982).

The Cretaceous and Jurassic units are directly overlain by Quaternary eolian material. Similar age alluvium can be found along the various stream courses cutting through the WSA (Haynes et al, 1972).

CAHONE CANYON WSA (CO-030-265D)

Within the boundaries of this WSA are found the Cretaceous Burro Canyon and Dakota Sandstone Formations which are overlain by Quaternary eolian material. The basal Cretaceous unit that crops out in Cahone Canyon is the Burro Canyon Formation. This unit consists of a series of fluvial sandstone, siltstone, shale and mudstone beds that locally have thin interbedded limestone units (Haynes et al, 1972). The Burro Canyon Formation is, in turn, directly overlain by the sandstone, shale and conglomerate units of the Dakota Sandstone. Within the WSA, the Dakota Sandstone is known to contain thin, discontinuous coal beds. These units have not been commercially exploited in the past and may have some economic potential (Cook, Personal Communication, 1982; Gentry, Personal Communication, 1982).

STRUCTURAL GEOLOGY AND TECTONICS

Tectonic features found within the GRA include west-northwest striking faults, shear zones, and joint systems. Northeast striking joint systems interact with these structural features to give the predominantly northeasterly trending drainage patterns of the southward draining tributaries of the San Juan River system. In the northeast portion of the GRA, northwest and northeast striking shear zones and joint systems control the course of the Dolores River Canyon east of Dove Creek, Colorado (Haynes et al, 1972).

The GRA is located within the Paradox Basin and is on the flank of the Dolores Anticline (Shawe, 1976). A series of parallel west-northwest striking faults, mapped in the Glade Mountain area east of the GRA, are the same orientation as many of the faults mapped in the northwestern portion of the GRA (Shawe, 1976).

Within the GRA, the Mesozoic section is thought to represent a conformable series of units with the only unconformity existing at the base of the Cretaceous Dakota Sandstone Formation (Shawe, 1976). Directly overlying the Mesozoic outcrops are a series of Quaternary alluvial, eolian and fluvial deposits.

Stratigraphic studies by oil companies and the United States Geological Survey have determined that the complete Paleozoic stratigraphic sequence probably underlies much of the GRA. The Precambrian basement complex is thought to exist at depth but is virtually unknown (Shawe, 1976; Baars et al, 1981; Heylmun, Personal Communication, 1982).

Subsurface northwest striking joint systems, faults, shear zones and fold structures have acted as traps for oil and gas in the Pennsylvanian Paradox Formation. Other subsurface joint systems and faults may be important in the localization of oil and gas deposits in the Squaw Canyon area (Scott et al, 1981; Buckner et al, 1981; Heylmun, Personal Communication, 1982). Subsurface structures in the Jurassic Morrison Formation may have provided pathways for uranium-vanadium bearing solutions and may have acted as sites for deposition of copper-silver mineralization in the Triassic Chinle, Wingate and Kayenta Formations.

Minor amounts of uranium-vanadium mineralization have been produced from prospects in the Morrison (Vanderwilt, 1947).

The following descriptions address the structural and tectonic characteristics of each of the individual WSA's within the Cross Canyon-Squaw/Papoose Canyons-Cahone Canyon GRA.

CROSS CANYON WSA (CO-30-265 & UT-060-229)

Structural features found within this WSA include northeast striking joint systems that control the major drainages of the area. The WSA is located within the Paradox Basin and may have subsurface faults that control and delineate oil, gas and uranium-vanadium deposits (Heylmun, Personal Communication, 1982; Cook, Personal Communication, 1982; Buckner et al, 1981; Scott et al, 1981; Vanderwilt, 1947).

Within the boundaries of the WSA, the exposed Mesozoic section is thought to represent a conformable series with the only mapped unconformity existing at the base of the Cretaceous Dakota Sandstone Formation (Shawe, 1976; Molenaar, 1981). Directly overlying the Mesozoic outcrops are a series of Quaternary alluvial deposits (Haynes et al, 1972).

Stratigraphic studies by oil companies have determined that the complete Paleozoic stratigraphic sequence probably underlies the WSA (Baars et al, 1981; Molenaar, 1981). The Precambrian basement is thought to exist at some depth but is virtually unknown (Shawe, 1976; Baars et al, 1981; Heylmun, Personal Communication, 1982).

SQUAW/PAPOOSE CANYONS WSA (CO-030-265A & UT-060-227)

Within these units west-northwest striking faults, shear zones, and joint systems cut across the dominant northeast structural grain. These tectonic features are thought to be a part of the Glade Fault Zone and may be important in the delineation of oil and gas deposits in the Pennsylvanian Paradox Formation (Buckner et al, 1981; Heylmun, Personal Communication, 1982). Northwest striking faults in the Pennsylvanian Paradox Formation are known to control and delineate oil and gas deposits (Buckner et al, 1981; Heylmun, Personal Communication, 1982). Other subsurface structures in the Jurassic Morrison Formation may control uranium-vanadium mineralization (Shawe, 1970; Carpenter, Personal Communication, 1982; Eyde, Personal Communication, 1982; Cook, Personal Communication, 1982).

The exposed Mesozoic section within the WSA is thought to represent a continous section with the only mapped unconformity existing at the base of the Cretaceous Dakota Sandstone. Stratigraphic studies by oil companies and the United States Geological Survey have determined that most of the Paleozoic section exists under the WSA (Baars et al, 1981; Molenaar, 1981; Shawe et al, 1968).

The Precambrian basement is thought to exist at depth (Baars et al, 1981). Quaternary alluvial deposits are found to directly overlie the Mesozoic section. The area has a number of producing oil and gas wells that are thought to be from structural traps in the Paradox Formation. Uranium mineralization in the general area of the WSA is currently being tested by Western Nuclear Incorporated. According to data supplied by Western Nuclear, the uranium mineralization is associated with structures in the Jurassic Morrison Formation (Cook, Personal Communication, 1982; Bowers, Personal Communication, 1982).

CAHONE CANYON WSA (CO-030-265D)

In the Mesozoic units exposed in the WSA are north-northeast striking joint systems that control the drainages of the upper portions of Cross and Cahone Canyons. Interacting with this structural system are a series of west-northwest striking joint systems that cut across the dominant northeast structural fabric to create a series of east-west trending canyons. All of these tectonic features may be important in the localization of structural traps for oil and gas in the underlying Paradox Formation and may be surface expressions of deep, subsurface structures of the Paradox structural Basin. The area lies within the Paradox Basin and has been studied by oil companies and the United States Geological Survey (Baars et al, 1981; Shawe et al, 1968). It is thought that most of the Paleozoic section exists under the WSA and that the Precambrian basement should exist at depth (Baars et al, 1981).

An unconformity has been mapped at the base of the Cretaceous Dakota Sandstone within most of the WSA. This probably represents a period of non-deposition and local transition from a terrestrial to marine environment (Shawe, 1976). Quaternary fluvial material directly overlies the outcrops of the Cretaceous sediments.

PALEONTOLOGY

Paleontological resources of the GRA have been studied by oil companies and the United States Geological Survey in conjunction with oil, gas and mineral exploration and stratigraphic studies. Numerous papers have been recently written describing the fossil content of various units in the Paleozoic and Mesozoic sections (Wengerd et al, 1958, Baars et al, 1981; Baars, 1966; Shawe et al, 1959; Bruckner et al, 1981; Krivanek, 1981; Shawe et al, 1968). It is known that the Jurassic Morrison Formation contains reptile, bird and mammal remains in other areas of Colorado (NPS File Data, 1982; Shawe et al, 1968). No reported occurrences of fossil material have been located within the GRA. In the Slick Rock District to the northeast of the GRA, fossil plant remains have been reported in the Salt Wash Member of the Morrison (Shawe et al, 1968).

The Cretaceous rocks that crop out throughout the GRA do not have any reported fossil occurrences of major scientific importance (NPS File Data, 1982). Coal seams within the Cretaceous Dakota Sandstone contain plant fossils and organic fragments (Cook, Personal Communication, 1982).

The Quaternary units cropping out within the GRA are not known to contain significant fossil remains (NPS File Data, 1982).

The following descriptions address the paleontological resources of each of the WSA's within the Cross Canyon-Squaw/Papoose Canyons-Cahone Canyon GRA.

CROSS CANYON WSA (CO-030-265 & UT-060-229)

There are no reported fossil occurrences or localities within this WSA (NPS File Data, 1982). In other areas of Colorado and Utah, the Jurassic Morrison and Salt Wash Formations are known to contain fossil plant, reptile, bird, and mammal remains. Coal seams in adjacent areas are known to contain fossil plant remains. These coal bearing units in the Cretaceous Dakota Formation are known to contain fossil invertebrate remains in southern Utah (NPS File Data, 1982; Shawe et al, 1968).

SQUAW/PAPOOSE CANYONS WSA (CO-030-265A & UT-060-227)

No occurrences of fossil material have been reported for this area (NPS File Data, 1982). An occurrence of fossil plant material was reported in association with coal seams in the Cretaceous Dakota Formation during the course of this study (Cook, Personal Communication, 1982). Within this area the Jurassic units are reported to contain uranium mineralization associated with organic material (Shawe et al, 1968).

CAHONE CANYON WSA (CO-030-265D)

There are no reported occurrences of fossil material from this area (NPS File Data, 1982). In other areas of Colorado the Dakota Formation contains abundant plant fossils associated with coal seams and carbonaceous shales (NPS File Data, 1982; Shawe et al, 1968).

HISTORICAL GEOLOGY

Knowledge of the Precambrian units in this area is based on limited published information, drill hole data and the character of outcrops in the Uncompahgre Uplift area.

During middle Precambrian time it is thought that the entire GRA was receiving sediments from both cratonic and island arc sources (Gilmour, Personal Communication, 1982). It appears that this was a time of persistent volcanism and tectonic activity. Marine deposition of eugeosynclinal sediments was interrupted by the ebb and flow of cratonic and island arc volcanism, and a period of extreme deformation was caused by plate collisions and regional uplifting. Older Precambrian units were metamorphosed, deformed, and intruded by a series of younger Precambrian mafic and felsic bodies. In this study area, the middle Precambrian rocks are thought to be mainly intrusive masses of granite that have partially absorbed the earlier gneiss and schist material.

Some of these intrusives contained anomalous amounts of metals, and have mineral deposits associated with them in other parts of Colorado and the western United States (Vanderwilt, 1947). Other base and precious metal deposit types known as exhalative deposits, are commonly found in Precambrian lithologies. These exhalative deposits, found in association with marine basins and rhyolitic volcanic systems, are commonly associated with the older Precambrian lithologies. Younger Precambrian or Paleozoic intrusives have intruded the older, highly metamorphosed and deformed complex of granite, gneiss, schist, pegmatite, aplite and lamprophyre lithologies. This younger granitic unit appears to have altered the units it intruded, and may be partially responsible for vein deposits of base and precious metals, beryl, and fluorspar that are found in other areas of Colorado. The Precambrian sequence is relatively unstudied in this area and has only been partially correlated with other areas of Colorado (Carter, 1965). In other parts of Colorado, the younger Precambrian is partially preserved, and consists of a thick section of clastic sediments. These lithologies represent a period of clastic deposition in a marine environment. From the seismic and drilling information that is currently available, it appears that the Precambrian units of this area are present at depths up to 10,000 feet (Baars, et al., 1981).

Approximately 1,700 million years before present (mybp) in the Precambrian, there was a period of uplift and rift formation that set the stage for all subsequent events in southwestern Colorado (Baars et al, 1981). These events which caused the formation of a large and deep rift basin adjacent to the Uncompahgre Uplift, caused by deep north-south compressional crustal forces (Baars, et al; 1981). With the formation of this deep basin, all sedimentation was restricted to the basin area, and the exposed deformed and intruded Precambrian basement complex was subjected to erosion. In areas east of the GRA, it is thought that this deposition continued through Permian time. Though the only Paleozoic rocks that have been encountered in drilling within the GRA are the Pennsylvanian and Permian lithologies, it is very probable that the full Paleozoic section exists throughout the GRA (Baars et al, 1981).

This period of early and middle Paleozoic deposition was characterized by the formation of a series of shallow basins along the deep rift valley. It is thought that these basins were progressively filled by Cambrian, Devonian, and Mississippian sediments (Baars et al, 1981). These sediments were then downfaulted into the rift zone during periods of tectonic activity. These periods of vertical movement were precursors to the extreme orogenic episodes that occurred in the beginning of Middle Pennsylvanian time, when Precambrian units were uplifted rapidly and formed highlands that shed between 15,000 and 20,000 feet of clastic sediments (Baars et al, 1981). These sediments filled the deeper parts of the adjacent structural trough. The highlands continued to exist throughout Pennsylvanian and Permian time, and were partially inundated by the clastic sequences of the Permian Cutler Formation.

During most of the Paleozoic, the deep rift basins teemed with plant and animal life. Reef communities grew on shallow marine bedrock highs in association with algal bioherms. Northwest striking faults and shear systems were active within the basins, and caused much in the way of up-and-down movement of the basement blocks that formed the floor of these basins. Certain basins along the rift zone were isolated by tectonic activity and became stagnant, inland, lacustrine bodies that were so filled with terrestrial sediments that they were unable to support life and became depositories of thick evaporite sequences (Baars et al, 1981). As a result of the formation of these evaporites, salt domes, anticlines, and diapirs formed with succeeding tectonic movements. These structural features were caused when the plastic evaporitic lithologies began to flow in response to tectonic stresses. The result of this movement was to form structures that displaced up to 14,000 feet of strata and created a series of diapirs and tight folds (Shoemaker, 1955, Baars, et al, 1981). Faults that formed along the margins and axial planes of these flowage structural features were active in Pennsylvanian and Permian time, and added to the structural complexity of the preexisting basins. These faults acted as traps for oil and gas deposits.

In the Mesozoic Era, the GRA was the site of fluvial and lacustrine deposition in a terrestrial environment. The Triassic Moenkopi Formation overlies the Paleozoic units in much of the GRA, and is thought to represent an era when shallow, fresh water lakes in enclosed basins were subjected to periods of dessication and shallow water, clastic deposition. The Moenkopi Formation is known for its saurian tracks and vertebrate fossils in other areas of western Colorado. Thus, it is reasonable to assume that amphibian and reptile life may have existed within the GRA during this period (NPS File Data, 1982). The Chinle, Wingate and Kayenta Formations of the Glen Canyon Group represent a time of Triassic sedimentation in a near-shore environment with episodes of eolian deposition of well cross-bedded beach and dune sand deposits. Certain fluvial and shallow water lacustrine deposits have also been identified in this sequence of sandstone, shale, siltstone, mudstone, limestone and conglomerate. It appears that the Triassic units were deposited along the margins of great, open seas and restricted inland basins that had existed since Paleozoic time. As the shorelines of these seas moved back and forth in response to orogenic episodes and basin filling, the localized environments in the GRA changed from marine to terrestrial. During this time, shallow-water and near-shore swamps were formed. In other areas of Colorado, these Upper Triassic near-shore sediments are the host for copper-silver "redbed" deposits that were deposited in areas of rapidly changing Eh-pH conditions in the aqueous solutions within the rock strata. The presence of these deposits in these other, widely dispersed areas of western Colorado is ample evidence that conditions favorable for these types of environments did, indeed, exist in the Traissic Period.

The Navajo Sandstone is thought to exist at depth in the western portion of the GRA and is thought to represent a period of inland sand dune accumulation in a terrestrial desert environment (Carter et al, 1965). This Triassic-Jurassic time unit thins to the southeast and probably was not deposited in the central and eastern portions of the GRA (Baars et al, 1981).

The unconformity between the Triassic section and the overlying Jurassic Entrada Formation is probably a local feature that represents a period of non-deposition. The Jurassic Entrada, is thought to have been deposited during a period of terrestrial fluvial and eolian deposition in small, restricted basins that eventually coalesced and buried the majority of the Uncompahgre Uplift features (Carter et al, 1965). The Jurassic Summerville and Morrison Formations were being deposited in near-shore lagoonal environments, or shallow-water marine and fluvial systems. Some fresh-water lacustrine and fresh-water fluvial deposits have also been identified from these rocks. As in the earlier Triassic section, mineral deposits are commonly found associated with limey sandstones, shales, and siltstones, deposited in shallow, neritic basins that have fluvial channels meandering through them. Uranium-vanadium mineralization occurs in these units as "roll-front" and organically precipitated "stream channel" deposits. "Roll front" deposits are elongate concretionary structures encompassed by rich vein-like concentrations of uranium-vanadium-bearing clay minerals. "Stream channel" deposits occur where uranium-vanadium waters encountered structural traps and clastic organic accumulations and, deposited the mineralization in a reducing environment. Such mineral deposits are very important economically, and are known to occur within the GRA. These deposits are thought to have been emplaced in an environment similar to that of the present lower Mississippi Basin. Fossil plant material from this period is indicative of a tropical environment that was adjacent to an active fluvial or lacustrine system.

During Lower Cretaceous time, the area was the site of shallow water deposition in a lagoonal or swamp environment. The Lower Cretaceous Burro Canyon Formation appears to have been deposited in a series of meandering river systems with adjacent terrestrial lakes. The terrestrial, clastic nature of this formation is thought to be characteristic of a beach or littoral environment (Young, 1955). The Upper Cretaceous Dakota Sandstone unconformably overlies the Burro Canyon Formation, and was probably deposited on an irregular upper surface of Burro Canyon rather than a true erosion surface (Carter et al, 1965). Portions of the Dakota Sandstone are found as channel fillings in the Burro Canyon paleosurface. From fossil evidence, it appears that the lower sections of the Dakota Sandstone were deposited in shallow basins or stream channels with the source of the material being eroded masses of Pennsylvanian and Permian rocks that were then exposed (Carter et al, 1965). The carbonaceous shales of the Dakota Sandstone are known to contain abundant plant remains, and were probably deposited in a near-shore swamp or lacustrine environment. Thin coal seams are known to exist within the Dakota Sandstone and may have economic potential.

Units of the Cretaceous Mancos Shale have been described as being sandstone and shale units deposited in a near-shore environment. In the GRA proper, these units are represented by resistant carbonaceous shales that cap isolated hills (Haynes et al, 1976).

The area was uplifted and subjected to erosion in Middle Tertiary times with the formation of the ancestral Colorado River Valley. Quaternary pediment, terrace and alluvial deposits were formed along the various fluvial systems that were established.

Figures II-1 through II-5 show oil wells in the vicinity of Cross and Squaw Canyons.

CROSS CANYON WSA (CO-030-265 & UT-060-229)

According to the geophysical and drilling information available, the Precambrian and much of the Paleozoic section is present under the WSA (Baars et al, 1981). No other detailed information on the lithologies encountered is currently available. Within the boundaries of the WSA, only the Jurassic and Cretaceous units are exposed.

The Jurassic rocks exposed in the WSA are thought to represent a period of fluvial and eolian deposition in small, restricted basins. The existing outcrops of the Jurassic Entrada, Summerville, and Morrison Formations have been heavily prospected for uranium/vanadium mineralization. Airborne radiometric anomalies were followed up by the Department of Energy and other government agencies under a number of different programs. To date, no major orebodies have been identified within the boundaries of the WSA. Conditions favorable for uranium-vanadium mineralization are thought to exist throughout the Jurassic Morrison Formation, but the only known mineralization is found associated with a stream channel in the Salt Wash Member adjacent to the WSA, and was investigated by the MSME/Wallaby field team (Cook, Field Notes, 1982).

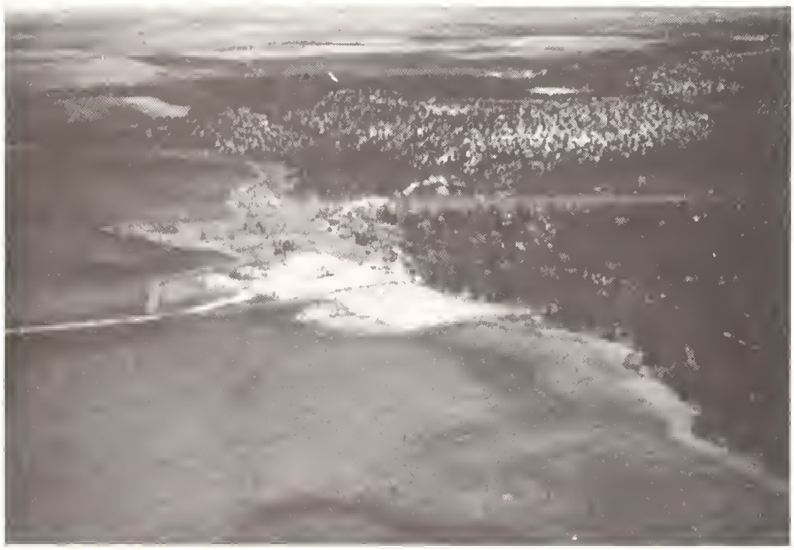
During Cretaceous time the area was the site of shallow water deposition in a lagoonal or swamp environment. The Lower Cretaceous Burro Canyon and Dakota Sandstone Formations contain thin coal seams that may have economic significance. During most of the Lower Cretaceous, however, the GRA was a part of a beach or littoral environment adjacent to the Mancos Basin of central Colorado (Young, 1955).

Units of the Cretaceous Mancos Shale have been described as being sandstone and shale units deposited in a near-shore environment, and outcrop as resistant units on mesa tops.

CROSS CANYON

FIGURE II-1

Dry hole



SQUAW CANYON

FIGURE II-2

Drill pad N of Squaw Canyon

SQUAW CANYON

FIGURE II-3

Drill pad N of Squaw Canyon

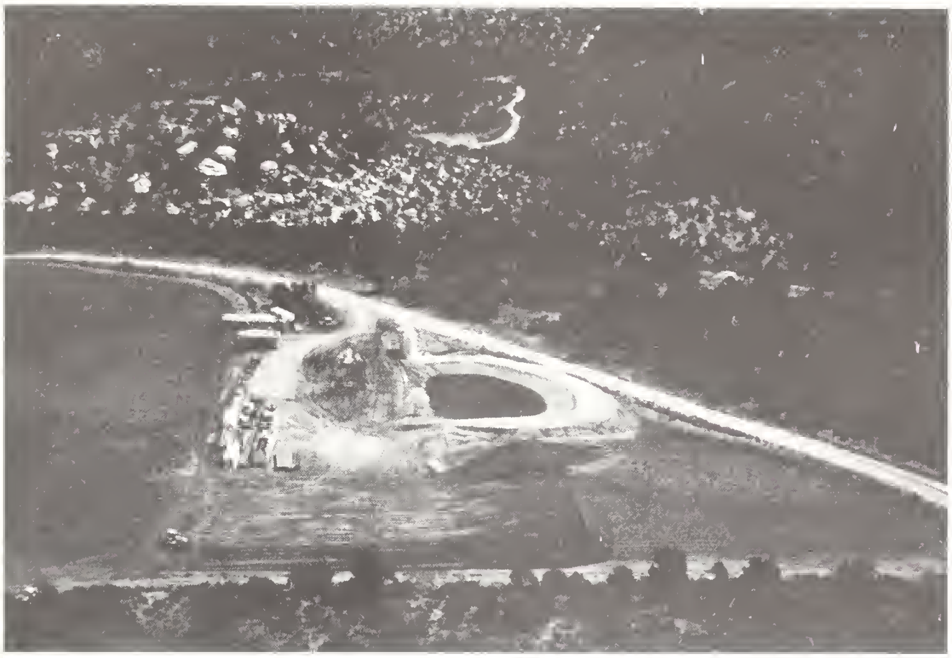


FIGURE II-4
Oil well N of
Squaw Canyon

SQUAW CANYON

FIGURE II-5
Oil well N of
Squaw Canyon

SQUAW CANYON

The rest of the Cretaceous section has been eroded. Quaternary fluvial and eolian deposits are found on mesa tops and along the canyons that cut through the area.

SQUAW/PAPOOSE CANYONS (CO-030-265A & UT-060-227)

According to the well information available, the Precambrian section is present under the WSA and was encountered in deep drill holes. No other information on the lithologies encountered is currently available. Within the boundaries of the WSA, only the Jurassic and Cretaceous units are exposed.

According to existing seismic and drilling data, Precambrian gneisses, schists and intrusive rocks are unconformably overlain by the Paleozoic section (Baars et al, 1981).

The pre-Pennsylvanian Paleozoic section is not known within the study area, but probably exists at some depth under the WSA. During this period of early and middle Paleozoic deposition, basins formed along the margins of the Uncompahgre Uplift were receiving sediments from the adjacent terrestrial highlands. These basins were filled with clastic and marine sediments and were, in turn, downfaulted into mobile rift zones. During Pennsylvanian times, thick evaporite sequences were laid down in these basins and subsequently deformed by tectonic stresses into salt anticlinal and domal features (Baars et al, 1981).

The Triassic Chinle-Wingate Formations are thought to have been deposited in a near-shore marine or lagoonal environment. The Jurassic section is represented by the Entrada, Summerville and Morrison Formations. These rocks are thought to represent near-shore lagoonal and shallow water marine conditions with periods of transggressive and regressive marine and lacustrine shorelines. Fluvial terrestrial and delta-floodplain deposits have also been identified from these rocks. The characteristic sandstone hoisted roll-front uranium-vanadium deposits, which occur in these lithologies and in other parts of Colorado, have not been identified within these units in the WSA. Occurrences of uranium-vanadium mineralization have been reported in adjacent areas to the WSA, in the Salt Wash Member of the Jurassic Morrison Formation.

During Cretaceous time the area was the site of shallow water deposition in a lagoonal or swamp environment. The Lower Cretaceous Burro Canyon and Dakota Sandstone Formations contain thin coal seams that may have economic significance. During most of the Lower Cretaceous, however, the GRA was a part of a beach or littoral environment adjacent to the Mancos Basin of central Colorado (Young, 1959).

Units of the Cretaceous Mancos Shale have been described as being sandstone and shale units deposited in a near-shore environment. In the WSA proper, these units are represented by the carbonaceous units of the Mancos upper section and represent periods of shallow water deposition in the lagoonal or swamp environment. Thin coal seams have been identified from the field reconnaissance efforts but have not been definitely correlated to these units. In other areas of Colorado and Utah, the Lower Cretaceous section has produced oil and gas (Brainard et al, 1962). The rest of the Cretaceous and Tertiary section has been eroded. Quaternary fluvial and eolian deposits are found along the northern boundary of the WSA and along the canyons that cut through the area and on mesa tops.

CAHONE CANYON WSA (CO-030-265D)

According to the well information available, the Precambrian section is present under the WSA and was encountered in deep drill holes. No other information on the lithologies encountered is currently available. Within the boundaries of the WSA, only the Jurassic and Cretaceous units are exposed.

According to existing seismic and drilling data, Precambrian gneisses, schists and intrusive rocks are unconformably overlain by the Paleozoic section (Baars et al, 1981).

The pre-Pennsylvanian Paleozoic section is not known within the study ara, but probably exists at some depth under the WSA. During this period of early and middle Paleozoic deposition, basins formed along the margins of the Uncompahgre Uplift were receiving sediments from the adjacent terrestrial highlands. These basins were filled with clastic and marine sediments and were, in turn, downfaulted into mobile rift zones. During Pennsylvanian times, thick evaporite sequences were laid dowwn in these basins and subsequently deformed by tectonic stresses into salt anticlinal and domal features (Baars et al, 1981).

The Triassic Chinle-Wingate Formations are thought to have been deposited in a near-shore marine or lagoonal environment. The Jurassic section is represented by the Entrada, Summerville and Morrison Formations. These rocks are thought to represent near-shore lagoonal and shallow water marine conditions with periods of transgressive and regressive marine and lacustrine shorelines. Fluvial terrestrial and delta-floodplain deposits have also been identified from these rocks. The characteristic sandstone hosted roll-front uranium-vanadium deposits which occur in these lithologies and in other parts of Colorado have not been identified within these units in the WSA. Occurrences of uranium-vanadium mineralization has been reported in the nearby areas in the Salt Wash Member of the Morrison.

During Cretaceous time the area was the site of shallow water deposition in a lagoonal or swamp environment. The Lower Cretaceous Burro Canyon and Dakota Sandstone Formations contain thin coal seams that may have economic significance. During most of the Lower Cretaceous, however, the GRA was a part of a beach or littoral environment adjacent to the Mancos Basin of central Colorado (Young, 1959).

Units of the Cretaceous Mancos Shale have been described as being sandstone and shale units deposited in a near-shore environment. In the WSA proper, these units are represented by the carbonaceous units of the Mancos upper section and represent periods of shallow water deposition in the lagoonal or swamp environment. Thin coal seams have been identified from the field reconnaissance efforts but have not been definitely correlated to these units. In other areas of Colorado and Utah, the Lower Cretaceous section has produced oil and gas (Brainard et al, 1962). The rest of the Cretaceous and Tertiary section has been eroded. Quaternary fluvial and eolian deposits are found along the canyons that cut through the area and on mesa tops.

SECTION III

ENERGY AND MINERAL RESOURCES

KNOWN MINERAL DEPOSITS

The Cross Canyon - Squaw/Papoose Canyons - Cahone Canyon GRA contains 3 principal commodities: oil and gas; carbon dioxide gas and helium, and uranium-vanadium. In addition, coal, base and precious-metals, construction stone, sand and gravel and clay are or have been productive deposits.

The GRA contains 5 producing oil, gas and carbon dioxide fields: the Bug, Patterson, Squaw Canyon, Papoose Canyon and Dove Creek. The Bug Field contains 6 producing oil and gas wells located in section 12, T36S, R25E and sections 16, 17, 21 and 22, T36S, R26E, San Juan County, Utah (Overlay C and Appendix A: Krivanek, 1981). Oil and gas is produced from a stratigraphic trap in the lower Desert Creek Zone of the Paradox formation, which is part of the Bug Field (Krivanek, 1981). The Patterson Field contains 3 shut-in oil and gas producing wells, located in sections 5 and 9, T38S, R25E, San Juan County, Utah (Overlay C and Appendix A; Martin 1981). Production tests from the 3 producing wells have recovered 15,752 barrels of oil and over 100,000 million cubic feet (Mcf) of gas. The Squaw Canyon field contains 3 producing oil and gas wells located in section 7 and 19, T38S, R26E, San Juan County, Utah (Overlay C). The Papoose Canyon and Dove Creek Fields contain 25 producing or past-producing wells (Overlay C and Jones and Murray, 1976). Cummulative production to January 1, 1975, was 902,872 barrels of oil and 4,690,095 Mcf of gas (Jones and Murray, 1976). Production is from a stratigraphic trap in the lower Desert Creek zone of the Paradox Formation (Krivanek, 1981).

Contained within the GRA are 43 known uranium-vanadium mines, located primarily in San Juan County, Utah (Overlay B). These deposits occur in the Jurassic Morrison formation. Production statistics are not known.

The following summarizes the other known deposits within the GRA (Overlays B and D).

Commodity - Type of Operation	Location	Operating Status*	Formation
Coal-underground mine mine (?)	T34S, R26E, sec. 22	Past Producer	Cretaceous Dakota Sandstone Fm.
Coal-open pit	T34S, R25E, sec, 26	"	" " "
Au,Ag, Pb, Zn, Cu-underground mine	T38N, R19W, sec. 7	"	Mesozoic section
Construction stone-quarry	T41N, R20W, sec. 13	Active (?)	Cretaceous Dakota Sandstone Fm (?)
Sandstone, sand & gravel pit	T40N, R18W, sec. 5	Active	Quaternary Alluvium (?)
Clay pit	T40N, R20W, sec. 16	Active (?)	Morrison or Mancos Sandstone Fms.
Sand & gravel pit	T39N, R17W, sec. 5	Active	Quaternary Alluvium
" " "	T40N, R18W, sec. 12	"	" "
" " "	T40N, R18W, sec. 21	"	" "
" " "	T40N, R19W, sec. 25	Active (?)	" "

The following addresses the known deposits in each of the WSA's with this GRA.

CROSS CANYON WSA (CO-030-265, UT-060-229)

There are no known deposits contained within the WSA.

SQUAW/PAPOOSE CANYONS WSA (CO-030-265A, UT-060-227)

The Squaw/Papoose Canyon WSA contains 1 producing oil well and 1 producing gas well (Overlay C, aerial photograph 063, Monument Canyon 7 1/2' Quad.). The wells are located in section 24, T39N, R20W in the Papoose Canyon Field.

CAHONE CANYON WSA (CO-030-265D)

There are no known deposits in the Cahone Canyon WSA.

KNOWN PROSPECTS, MINERAL OCCURRENCES AND MINERALIZED AREAS

The following table summarizes the known prospects located within the Cross Canyon-Squaw/Papoose Canyons - Cahone Canyon GRA:

Commodity-Type	Number
Oil & gas dry wells	at least 50
Uranium or oil and gas exploration holes	at least 50
Coal prospects	5
Uranium prospect	1
Uranium occurrence	1
Silver prospect	1

Exploration drilling for uranium has been done by Western Nuclear (Appendix A: evaluations and topographic maps).

The following addresses the known prospects, mineral occurrences and mineralized areas in each WSA contained within the GRA.

CROSS CANYON WSA (CO-030-265/UT-060-229)

The Cross Canyon WSA contains several areas in which exploration drilling is being undertaken (Refer to aerial photography and topographic maps in Appendix A). This drilling activity is primarily being completed by Western Nuclear.

SQUAW/PAPOOSE CANYONS WSA (CO-030-265A/UT-060-227)

There are no known prospects in the Squaw/Papoose Canyons WSA.

CAHONE CANYON WSA (CO-030-265D)

The Cahone Canyon WSA contains 2 dry wells located in sections 22 and 26, T39N, R19W (Overlay C).

MINING CLAIMS, LEASES AND MATERIAL SITES

As of June 14, 1982, approximately 8,198 unpatented mining claims were located within this GRA. Of this figure, approximately 1,189 claims are within the Cross Canyon and Squaw/Papoose Canyons WSA's. The remaining claims are principally situated northwest and southwest of the aforementioned WSA's. A large portion of the claims are controlled by Atlas Corporation, Cotter Corporation, Fremont Energy Corporation, Minatome Corporation and Plateau Resources.

Three oil and gas leases are located adjacent to the Cross Canyon and Squaw/Papoose Canyon WSA's, in Sections 15 and 32, T37S, R26E and section 16, T38S, R26E, San Juan County, Utah (Overlay A; Appendix B, Index 1, nos. 52-54). Another oil and gas lease is located 2 miles west of the Squaw/Papoose Canyons WSA, in section 19, T38S, R26E. The leases are delineated in Appendix B, Index to Overlay A.

As of June, 1982, there were no patented mining claims in the GRA.

Information on leases was not obtained for the entire GRA. Please refer to the Oil and Gas Plats (Appendix A).

The following addresses the mining claims, leases, and material sites in each WSA contained within the GRA.

CROSS CANYON WSA (CO-030-265, UT-060-229)

Unpatented mining claim data was obtained from the Bureau of Land Management Geographic Index (Appendix C). Since the Geographic Index only locates claims by township, range, section and quarter-section, it is difficult to determine if claims situated in a section cut by the WSA boundary are in fact within the WSA. The location notices and maps filed by the claimants will provide an accurate account of claims within the WSA. As of June 14, 1982, approximately 536 unpatented mining claims were located in the WSA (Overlay A). There were no patented claims, in the WSA.

There are a number of oil and gas leases located within the WSA. Please refer to the Oil and Gas Plats and Master Title Plats in Appendix A.

SQUAW/PAPOOSE CANYONS WSA (CO-030-265A, UT-060-227)

As in Cross Canyon WSA, an accurate number of unpatented claims cannot be determined without the location notices and maps. As of June 14, 1982, approximately 626 unpatented mining claims were located in the Squaw/Papoose Canyons WSA (Overlay A). There were no patented mining claims in the WSA.

As of August 27, 1982, there were a number of oil and gas leases contained within the WSA. Please refer to the Oil and Gas Plats and Master Title Plats in Appendix A.

CAHONE CANYON WSA (CO-030-265D)

As of June, 1982, no patented or unpatented claims in this WSA. There are a number of leases contained within the WSA. Please refer to the Oil and Gas Plats and Master Title Plats in Appendix A.

MINERAL DEPOSIT TYPES

The mineral deposit types of the Cross Canyon-Squaw/Papoose Canyons - Cahone Canyon GRA can be grouped by mineral occurrence in three broad categories: oil, gas, helium, carbon dioxide, and coal; uranium and vanadium; and copper, silver, clay, sand, gravel and construction stone.

Located within the GRA are five major producing gas and oil fields, along with other smaller minor fields (See Overlay C). The five major fields include Bug, Dove Creek, Papoose Canyon, Squaw Canyon, and Patterson. The first three fields produce gas or oil from a stratigraphic trap in the lower Desert Creek zone of the Pennsylvanian Paradox Formation. Production occurs in the penesaline facies of the Desert Creek zone, a suite of anhydrites, dolomites, limestone, and black, organic-rich shales. Common to this facies are mounds whose main constituent is carbonate mud (Reid and Berahorn, 1981). The mounds were apparently formed by algal colonies which trapped eroded sediments and debris. The algal mound is the "pay zone" whose porosity development is the controlling factor in reservoir limits (Reid and Berahorn, 1981). The cumulative production of the Desert Creek zone through 1979 is 1,556,251 barrels of oil, with estimated reserves at 2,100,000 bar rels (Reid and Berahorn, 1981). The Squaw Canyon field produces from the Desert Creek and Upper Ismay Zone, of the Paradox Formation. In addition, Patterson Field produces from the Ismay Zone (Reid and Berahorn, 1981). The most productive zone in the Ismay is the marine shelf facies, a series of marine limestones, dolomites, black and red shales, siltstones, and sandstones, which is characterized by a lack of evaporites (Reid and Berahorn, 1981). Accumulation is stratigraphic, occurring in fossiliferous limestone units of coral colonies which may be a series of stacked algal mounds (Reid and Berahorn, 1981). The average well recovery in this zone is 163,000 barrels of oil on 40-acre spacing (Reid and Berahorn, 1981). Subsurface structural features may have also aided in localizing the pay zones within the favorable stratigraphy.

Coal occurs in the Cretaceous Dakota Sandstone. The Dakota Sandstone is a yellowish-brown to gray friable to quartzitic sandstone and conglomeratic sandstone with interbedded carbonaceous non-marine shale (Williams, 1964). The Dakota Sandstone can be divided into three members: an upper sandstone member, a middle coal-bearing member, and a lower conglomeratic sandstone member (Landis, 1959). The coal beds are lenticular and are relatively impure. The coal is generally ranked as high-volatile bituminous (Landis, 1959).

The uranium and vanadium deposits occur in the GRA in the Jurassic Morrison Formation as carnotite. Carnotite, a uranium and vanadium oxide, is a secondary mineral which has been deposited by waters that were in contact with primary uranium and vanadium minerals. The uranium-vanadium mineralization occurs mainly in two members of the Morrison Formation, the Salt Wash (Lower Morrison), and Brushy Basin (Upper Morrison). The Salt Wash formed as a large alluvial fan by an agrading system of braided streams. It is composed mostly of interstratified units of sandstone and claystone (Craig et al, 1959). The Brushy Basin consists mainly of variegated claystones with few lenticular conglomeritic sandstone strata.

This formed in fluvial and lacustrine environments with large amounts of clay (Craig et al, 1959). It is thought the introduction of the ore was done by mineral-bearing solutions that seeped through permeable layers after sediments accumulated. The source of the primary minerals is currently in dispute (Craig et al, 1959).

The sand and gravel deposits are usually Quaternary age alluvium, deposited by the rivers in each of the canyon systems in the GRA. The construction stone was mined from the Dakota Formation. Clay was mined from the Morrison Formation and Mancos Shale. The copper and silver prospects were located in the Mesozoic section. No further information on the clay, copper, and silver deposits was available.

The following addresses the mineral deposit types in each WSA in the Cross Canyon-Squaw/Papoose Canyons-Cahone Canyon GRA.

CROSS CANYON WSA (CO-030-265, UT-060-229)

There are no known mineral deposits in the Cross Canyon WSA. However, the field consultants noted a two-foot coal seam in the Cretaceous Dakota Sandstone (Field notes, Appendix A).

SQUAW/PAPOOSE CANYONS WSA (CO-030-265A, UT-060-227)

This WSA contains one producing oil, and one producing gas well, both of which are located in the Papoose Canyon Field. Please see the above GRA discussion for a complete description of the mineral deposit types of the Papoose Canyon Field.

CAHONE CANYON WSA (CO-030-265D)

There are no known mineral deposits in this WSA.

MINERAL ECONOMICS

The inherent nature of discussing the economics of the minerals existing within the Cross Canyon - Squaw/Papoose Canyons - Cahone Canyon GRA and its WSA's can only provide for a general approach inasmuch as there are many economic factors that enter into the development of an ore body. These include access, market value, grade, transportation, recovery and extraction methods, etc. Therefore, the discussion herein addresses the U.S. and Colorado demand of the production status of each of the existing minerals in the WSA.

The mineral resources found in the Cross Canyon-Squaw/Papoose Canyons-Cahone Canyon GRA include oil, gas, carbon dioxide, helium, coal, uranium and vanadium, copper, silver, clay, sand and gravel, and construction stone.

The GRA contains five producing oil, gas, and carbon dioxide fields. These include the Bug, Patterson, Squaw Canyon, Papoose Canyon and Dove Creek fields. Production tests from three wells in the Patterson Field have recovered 15,752 barrels of oil, and over 100,000 million cubic feet (Mcf) of gas (Jones and Murray, 1967). Cumulative production to 1-1-75 for the Papoose Canyon and Dove Creek Fields was 902,872 barrels of oil and 4,690,095 Mcf of gas (Jones and Murray, 1976). Production statistics for the Bug and Squaw Canyon fields were not available. These deposits will have continuing importance as long as the United States is a net importer of oil and gas. Current demand for petroleum products will maintain current levels or increase in the future (Petroleum Times Price Report, Oct. 1982). Exploration activity in western Colorado has slackened in the last six months with the number of active rigs drilling dropping approximately 15% (Heylmun, Personal Communication, 1982). Areas of current drilling activity include the Paradox Basin of Colorado and Utah, and areas north of the Colorado River in Mesa, Garfield, and Moffat Counties, Colorado (Heylmun, Personal Communication, 1982).

Coal in the GRA is produced mainly from Cretaceous Dakota sandstone. The GRA contains two coal mines (refer to Overlay B) about which little is known. Besides the fact that both are past producers, no other production statistics are available. Coal production for Colorado mines is currently at an all time high. Approximately 20,000,000 tons of high-grade low-sulphur coal was produced from open pit and underground operations (Colo. Div. Mines Rept., 1980; and Schwochow, 1978). The future looks encouraging for coal as more and more utilities are switching back to coal for power generation (Schwochow, 1978; Colo. Div. Mines Rept., 1980). Changes in technology and improvements in combustion/distillation techniques will increase the demand for Colorado coal, and coal byproducts (Gentry, Personal Communication, 1982).

Energy mineral occurrences (uranium and vanadium) in the GRA are known in the Jurassic Morrison Formation. Current production is down from past production levels due to a general drop in the price of uranium (Eng. and Mining Journal, Dec. 1982). Uranium and vanadium are currently being produced at very little or no profit by many of the major mining operations in Colorado (Carpenter, Personal Communication, 1982). The GRA contains more than 40 known uranium deposits (Production statistics are not available). Future demand for uranium and vanadium is dependent on foreign production and the needs of the nuclear generating industry (Schwochow, 1978).

Copper and silver were produced from the Mesozoic sections (further information was not available). Currently, a strong demand for precious metals exists in the U.S. and Colorado due to high prices. Production and demand for base metals, however, is down from past levels due to a general down-turn in the United States' economy (Eng. and Mining Journal, Dec., 1982). Commodities such as copper, lead, zinc, manganese, iron and molybdenum are not being currently produced at a substantial profit by any of the major mining operations in Colorado (Eng. and Ming. Journal, Dec. 1982; Carpenter, Personal Communication, 1982).

Clay, sand and gravel, and construction stone comprise the industrial minerals in the GRA. This group is considered to be "high place value" industrial minerals. "High place value" minerals are of economic value only when the deposits are readily accessible, and in close proximity to a market.

The economic viability of the mineral resources in the WSA's in the GRA are summarized as follows:

WSA	MINERAL POTENTIAL	ACCESSIBILITY	ECONOMIC POTENTIAL[a]
Cross Canyon WSA (CO-030-265, UT-060-229)	Oil, Gas*	Unknown	Unknown
	Carbon Dioxide & Helium*	-do-	-do-
	Dimension Stone*	-do-	-do-
	Structural &	-do-	-do-
	Bentonitic clays*	-do-	-do-
	Uranium-Vanadium*	-do-	-do-
Squaw/Papoose Canyon WSA (CO-030-265A, UT-060-227)	Oil, Gas	Good	Good
	Carbon Dioxide & Helium*	Unknown	Unknown
	Dimension Stone*	-do-	-do-
	Structural & Bentonitic clays*	-do-	-do-
Cahone Canyon WSA (CO-030-265D)	Oil, Gas*	Unknown	Unknown
	Carbon Dioxide & helium*	-do-	-do-
	Dimension Stone*	-do-	-do-
	Structural & Bentonitic clays*	-do-	-do-

[a] The economic potential rating is notwithstanding market demand fluctuations.

*No known deposits or mineralization present in WSA. See Section IV for explanation of the economic potential.

SECTION IV

LAND CLASSIFICATION FOR GEM RESOURCES POTENTIAL

After thoroughly reviewing the existing literature and data base sources, MSME/Wallaby personnel plotted all known mineral occurrences, mines, prospects, oil and gas fields, sand and gravel operations, processing facilities, mining claims, mineral leases, and the locations of anomalous geochemical samples from the National Uranium Resource Evaluation - Hydrological Stream Sediment Reconnaissance - Airborne Radiometric and Magnetic Survey (NURE-HSSR-ARMS) programs. This plotted information and the data bases on each WSA was made available to a multi-faceted team of experts which made three successive evaluations of the GEM resource potential of each of the WSA's.

The team or panel of geological experts was comprised of:

Dr. Paul Gilmour: Base and precious metal deposits in western U.S. and Canada, expert on Precambrian mineral resources.

Mr. Ted Eyde: Base and precious metal deposits in western U.S., expert on industrial mineral resources.

Mr. Annan Cook: Base and precious metal deposits in western U.S., expert on porphyry deposits and mine evaluation.

Mr. Edward Heylmun: Oil, gas and oil shale deposits of western U.S.

Dr. Robert Carpenter: Mineral deposits of Colorado and western U.S., expert on geology of Colorado.

Dr. Donald Gentry: Expert in coal and oil shale deposits of Colorado and western U.S.

Dr. Larry Lepley: Expert in remote sensing and geothermal resources.

Mr. Walter E. Heinrichs: Geophysics and base and precious metal deposits of western U.S., expert on porphyry copper deposits.

As indicated earlier, Dr. Gilmour and Mr. Cook made certain field investigations as result of the base data analysis phase. The purpose of the field investigations was to either verify the existing data or assess relatively unknown areas. Dr. Lepley reviewed all aerial photographs for observable anomalies, which were then investigated by the field team, or verified against the existing base data.

The evaluations were then made on the basis of examination of the data bases, field investigations and the individual experiences of the members of the panel in such areas as base and precious metal, industrial and energy mineral deposits; oil and gas deposits; and geothermal resources. In the course of these evaluations, every attempt was made to objectively rate the potential for a particular commodity within the respective study area. In this effort, the evaluation criteria proposed by the Bureau was rigorously used. The classification scheme used is shown in Table IV-1. In many cases the lack of information did not allow for a full determination of the GEM resource potential and the panel was forced to leave some areas unranked or classified for some commodities. The situation thus arises where there is an area that has been unclassified for a commodity, despite to it's reported occurrence, because it is next to an area where there is insufficient data to make a meaningful attempt at classification. Nonetheless, each resource has been additionally rated as to what level of confidence the panel of experts attached to the selected classification level. This is denoted by the letter associated with each rate classification. These are defined in Table IV-1.

A further restraint on this classification and delineation effort comes in the area of the lack of subsurface information. Some areas are very well known from past exploration efforts and have an abundance of subsurface information. Other areas are practically unknown due to an absence of any past exploration or development efforts.

The WSA's, for the most part, are not well known geologically. For this reason, our expert team had to extrapolate geologic information from adjacent areas to make any sort of reasonable classification with some level of confidence. The following pages address those resources considered to be leasable, locatable, and/or salable with associated maps (Figures IV-1 through IV-3) locating the resource area.

TABLE IV-1
RESOURCE RATING CRITERIA

CLASSIFICATION SCHEME

1. The geologic environment and the inferred geologic processes do not indicate favorability for accumulation of mineral resources.

2. The geologic environment and the inferred geologic processes indicate low favorability for accumulation of mineral resources.

3. The geologic environment, the inferred geologic processes, and the reported mineral occurrences indicate moderate favorability for accumulation of mineral resources.

4. The geologic environment, the inferred geologic processes, the reported mineral occurrences, and the known mines or deposits indicate high favorability for accumulation of mineral resources.

LEVEL OF CONFIDENCE SCHEME

A. The available data are either insufficient and/or cannot be considered as direct evidence to support or refute the possible existence of mineral resources within the respective area.

B The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C. The available data provide direct evidence, but are quantitatively minimal to support or refute the possible existence of mineral resources.

D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resource.

LEASABLE RESOURCES

CROSS CANYON WSA (CO-030-265/UT-060-229)

Resource	Classification	Comments
Oil & Gas	4D	Oil and gas production, near the WSA, is from the Desert Creek Zone in the Pennsylvanian Paradox formation which extends through the WSA, known leasing area.
Coal	2B	Coal-bearing units have been eroded. Prospectively valuable for coal resources.
Brines & Potash	3B	Unknown potential, prospectively valuable area for potassium.
Carbon Dioxide & Helium	4D	Producing well near the WSA.

SQUAW-PAPOOSE CANYONS WSA (CO-030-265A/UT-060-227)

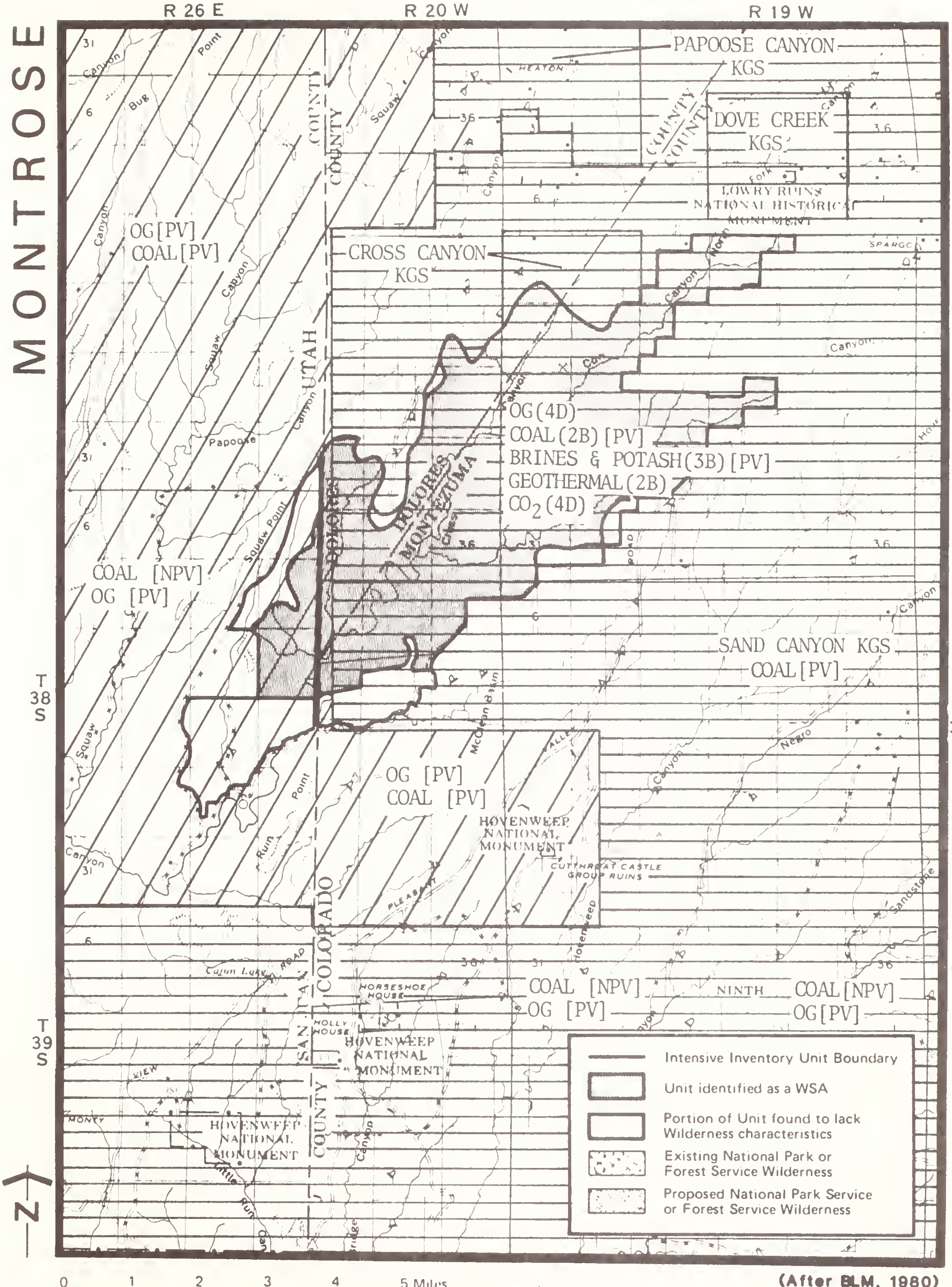
Resource	Classification	Comments
Oil & Gas	4D	Oil and gas production, near the WSA, is from the Desert Creek Zone in the Pennsylvanian Paradox formation which extends through the WSA, known leasing area.
Coal	2B	Coal-bearing units have been eroded. Prospectively valuable for coal resources.
Brines & Potash	3B	Unknown potential, known prospectively valuable area for potassium.
Geothermal	2B	Unknown potential
Carbon Dioxide & Helium	4D	Producing well near the WSA.

Leasable Resources (cont)

CAHONE CANYON WSA (CO-030-265D)

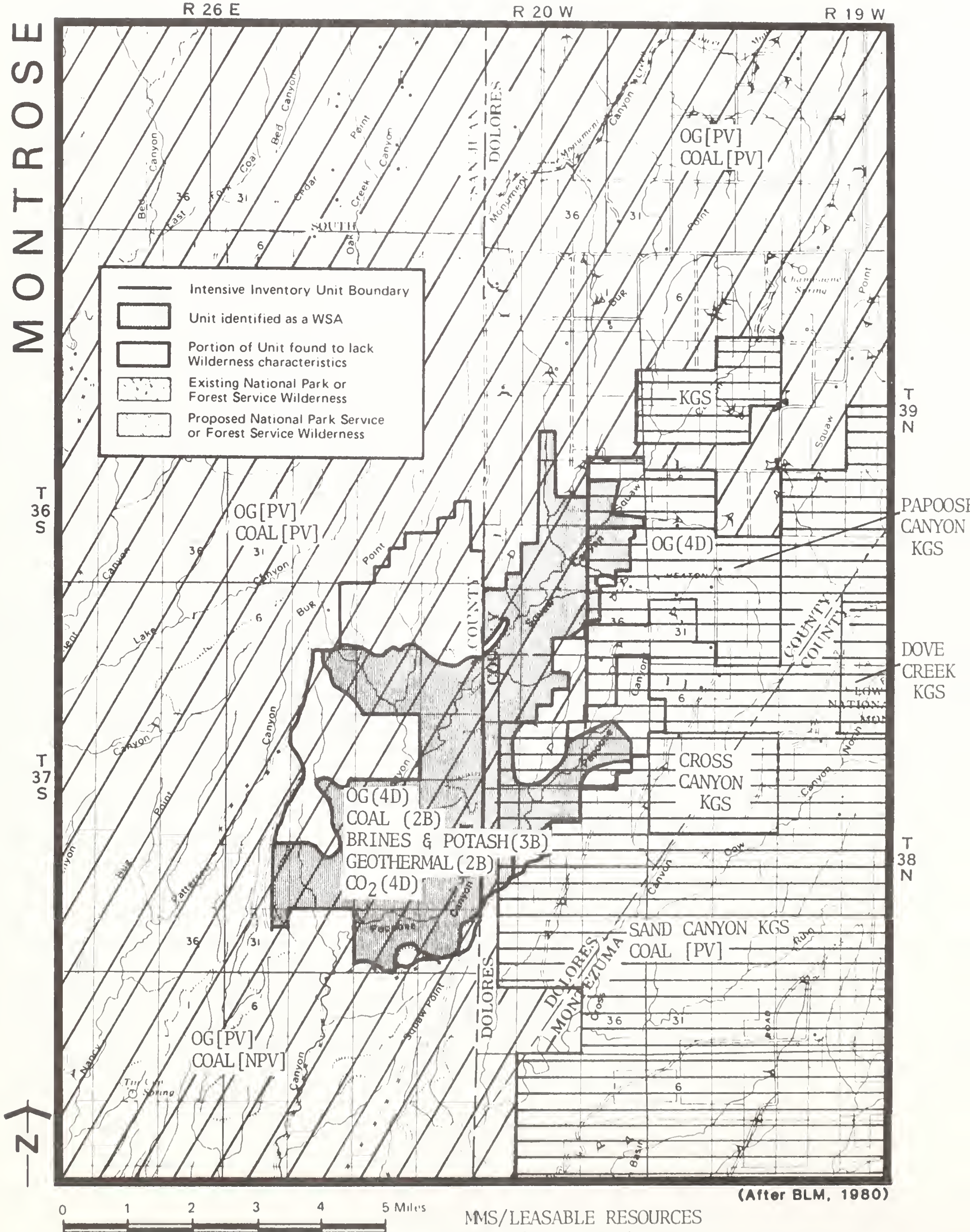
Resource	Classification	Comments
Oil & Gas	4D	Oil & gas production, near the WSA, is from the Desert Creek Zone in the Pennsylvanian Paradox formation which extends through the WSA, known leasing area.
Coal	3C	The Cretaceous Dakota formation is present. Prospectively valuable for coal resources.
Brines & Potash	3B	Unknown potential, known prospectively valuable area for potassium.
Geothermal	2B	Unknown potential
Carbon Dioxide & Helium	4D	Producing wells outside the WSA.

CO-030-265 Cross Canyon



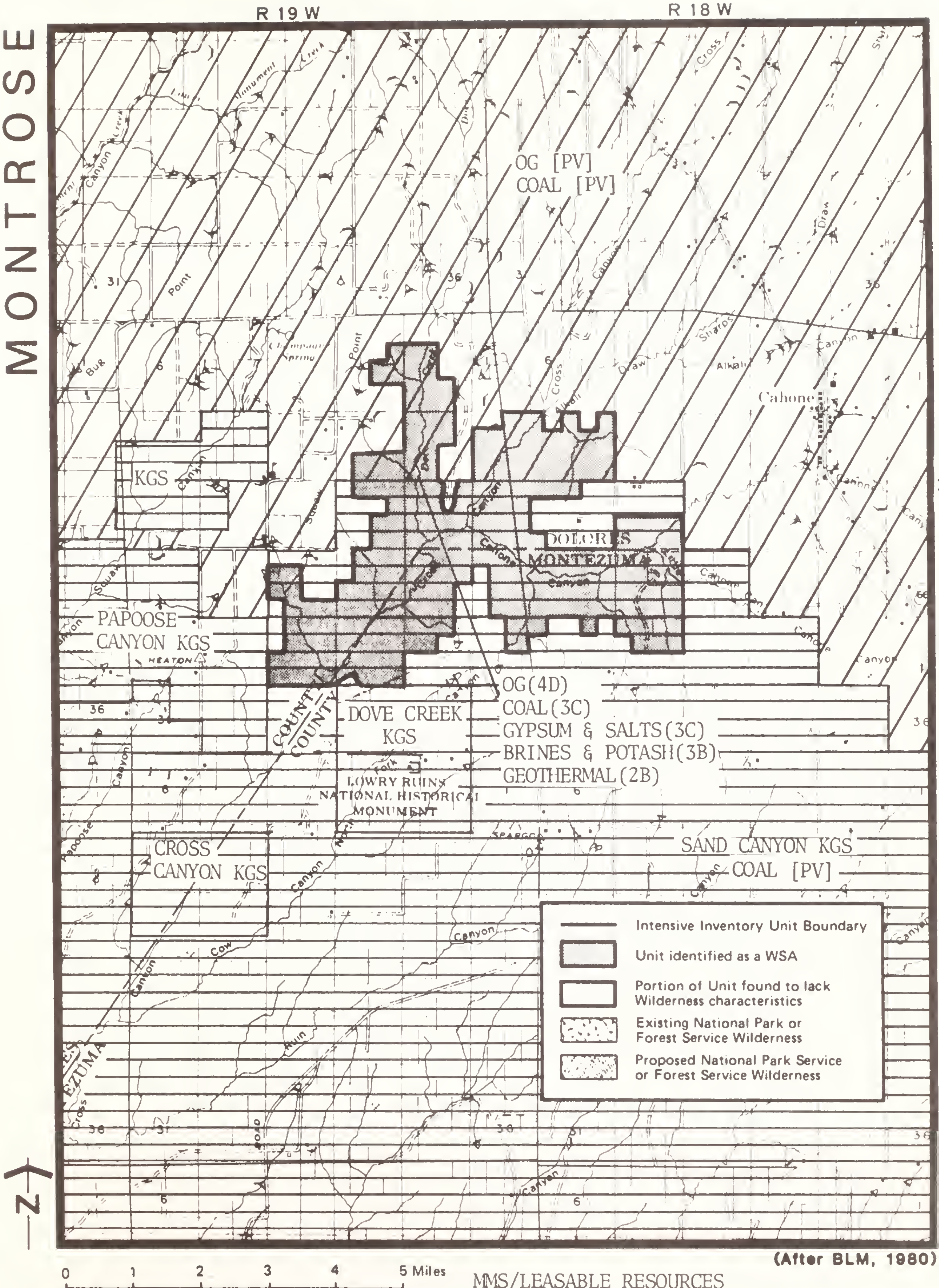
MMS/LEASABLE RESOURCES
Figure IV-1a

CO-030-265A Squaw/Papoose Canyons



MMS/LEASABLE RESOURCES
Figure IV-1b

CO-030-265D Cahone Canyon

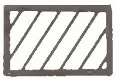


(After BLM, 1980)

MMS/LEASABLE RESOURCES
Figure IV-1c

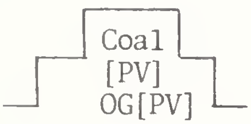
LEGEND FOR MINERALS MANAGEMENT SERVICE CLASSIFICATIONS

Defined KGS and/or Coal Leasing Areas



Areas Prospectively Valuable for Sodium or Potassium

Defined Oil Shale Leasing Area



Areas Identified as Prospectively Valuable for Coal or Oil, Gas

Coal [NPV]
OG [NPV]

Areas Identified as Not Being Prospectively Valuable for Coal, or Oil, Gas

LOCATABLE MINERALS

CROSS CANYON WSA (CO-030-265 & UT-060-229)

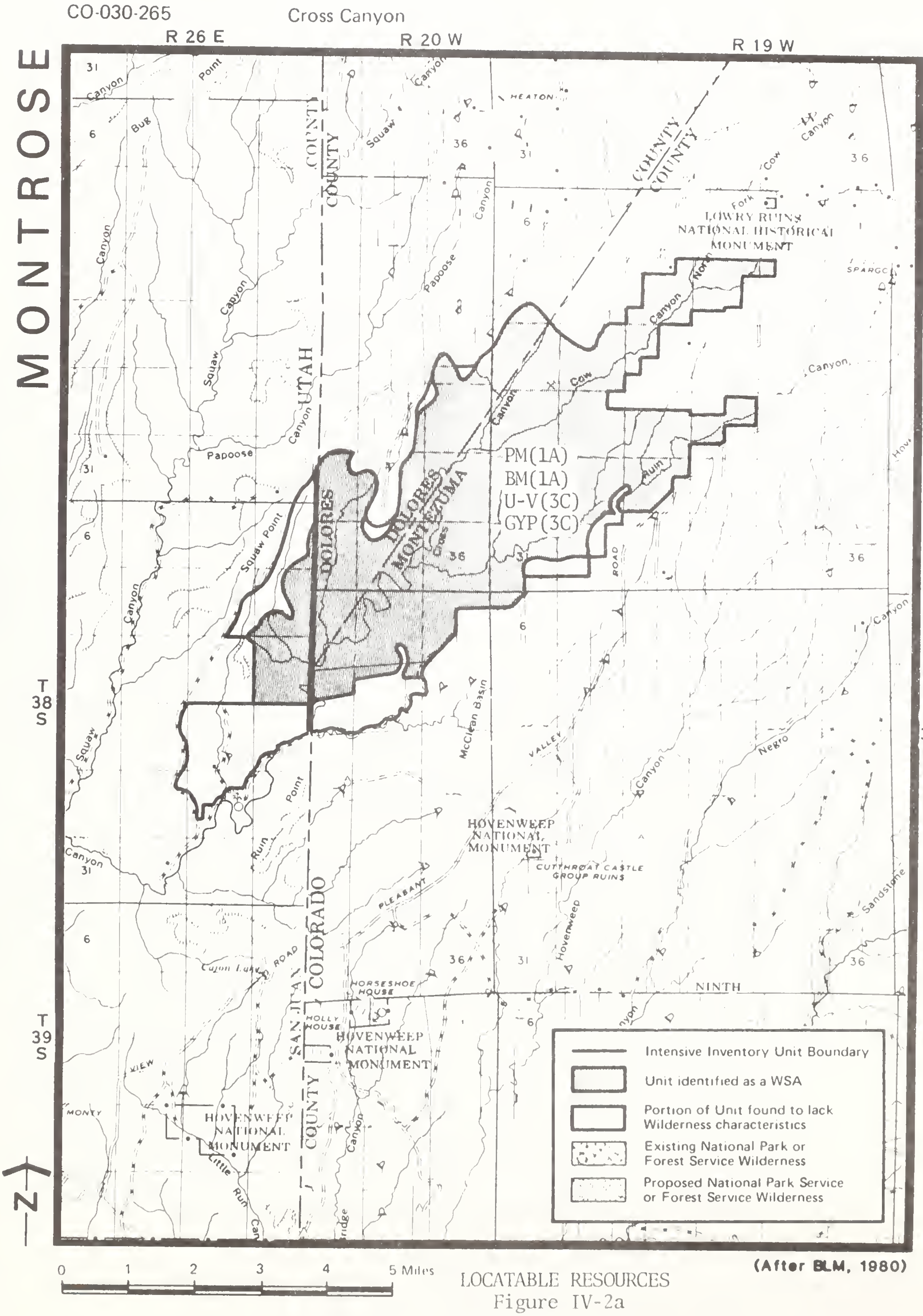
Resource	Classification	Comments
Precious Metals	1A	Unknown potential in Mesozoic section.
Base Metals	1A	Unknown potential in Mesozoic section.
Locatable Energy Minerals	3C	U-V mineralization in Salt Wash Member of Jurassic Morrison Formation, adjacent occurrence with production.
Other Locatable Minerals Gypsum	(3C)	Gypsum is known to occur in the underlying Paradox Formation. The economic potential is rated low to moderate.

SQUAW/PAPOOSE CANYONS WSA (CO-030-265A & UT-060-227)

Resource	Classification	Comments
Precious Metals	1A	Unknown potential in Mesozoic section.
Base Metals	1A	Unknown potential in Mesozoic section.
Locatable Energy Minerals	3C	U-V mineralization in Salt Wash Member of Jurassic Morrison Formation, adjacent occurrence with production.
Other Locatable Minerals Gypsum	(3C)	Gypsum is known to occur in the underlying Paradox Formation. The economic potential is rated low to moderate.

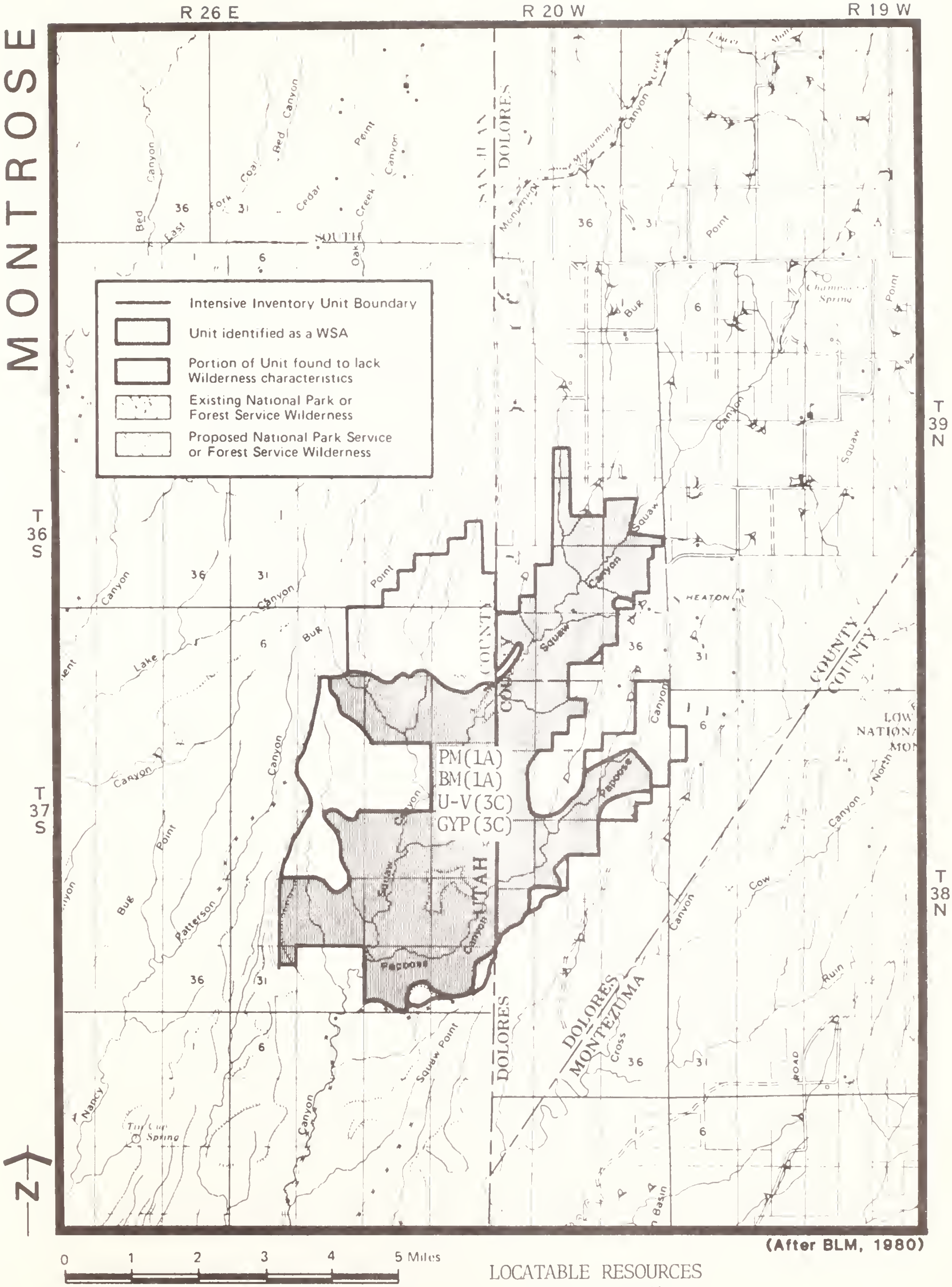
CAHONE CANYON WSA (CO-030-265D)

Resource	Classification	Comments
Precious Metals	1A	Unknown potential in Mesozoic section.
Base Metals	1A	Unknown potential in Mesozoic section.
Locatable Energy Minerals	2B	U-V mineralization potential in Salt Wash Member of Jurassic Morrison Formation, nearby outcrops with mineralization.
Other Locatable Minerals Gypsum	(3C)	Gypsum is known to occur in the underlying Paradox Formation. The economic potential is rated low to moderate.



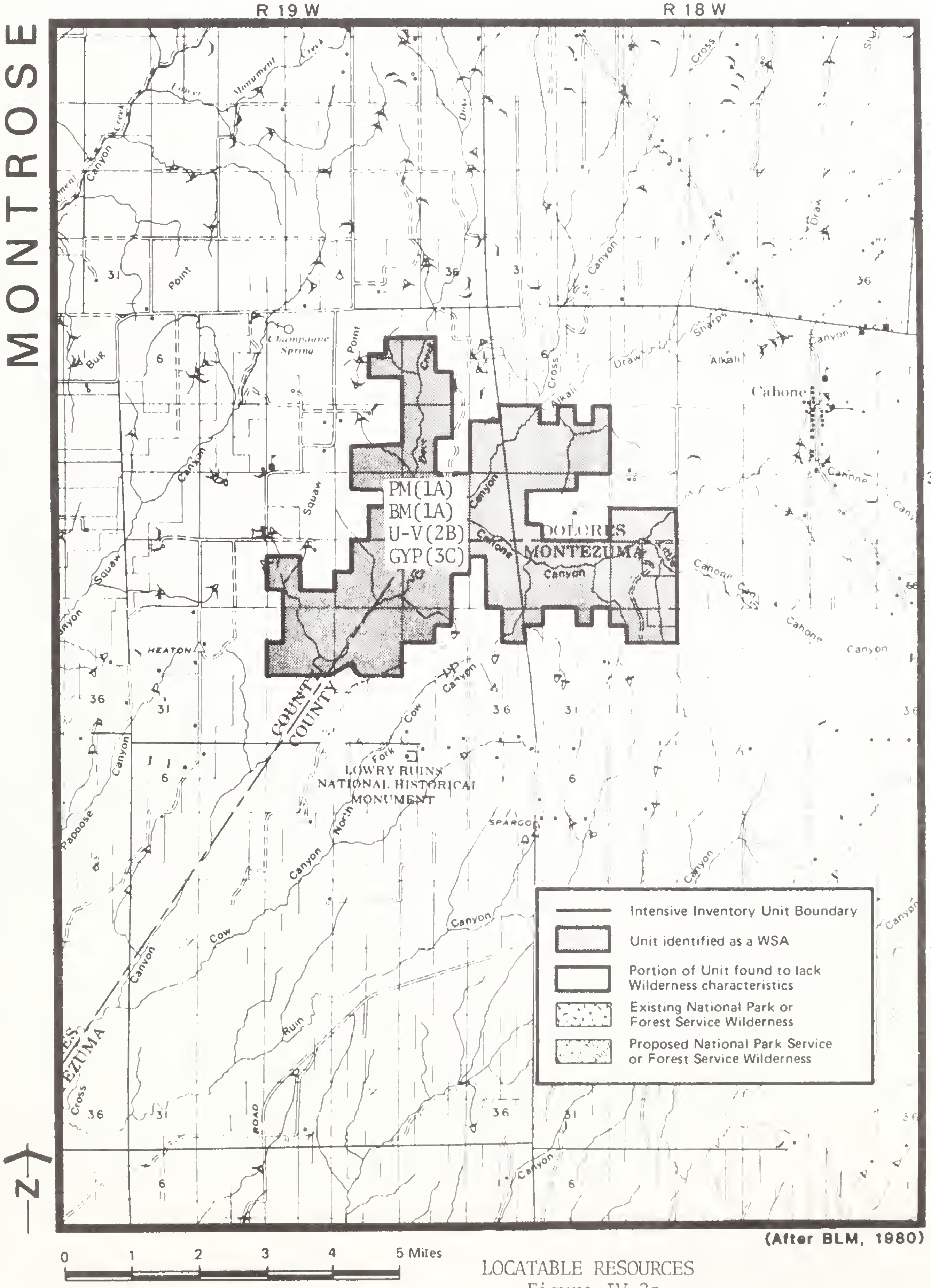
LOCATABLE RESOURCES
Figure IV-2a

CO-030-265A Squaw/Papoose Canyons



LOCATABLE RESOURCES
Figure IV-2b

CO-030-265D Cahone Canyon



(After BLM, 1980)

LOCATABLE RESOURCES
Figure IV-2c

SALABLE RESOURCES

CROSS CANYON WSA (CO-030-265 & UT-060-229)

Resource	Classification	Comments
Dimension Stone	4D	The economic potential is rated as low to moderate. The Dakota Sandstone may contain favorable units.
Structural & Bentonitic Clays	4D	The economic potential is rated as low to moderate. The Morrison and Mancos Shale Formations may contain favorable units.
Limestone	3C	The Paradox Formation may contain favorable units. The economic potential is rated as low to moderate.

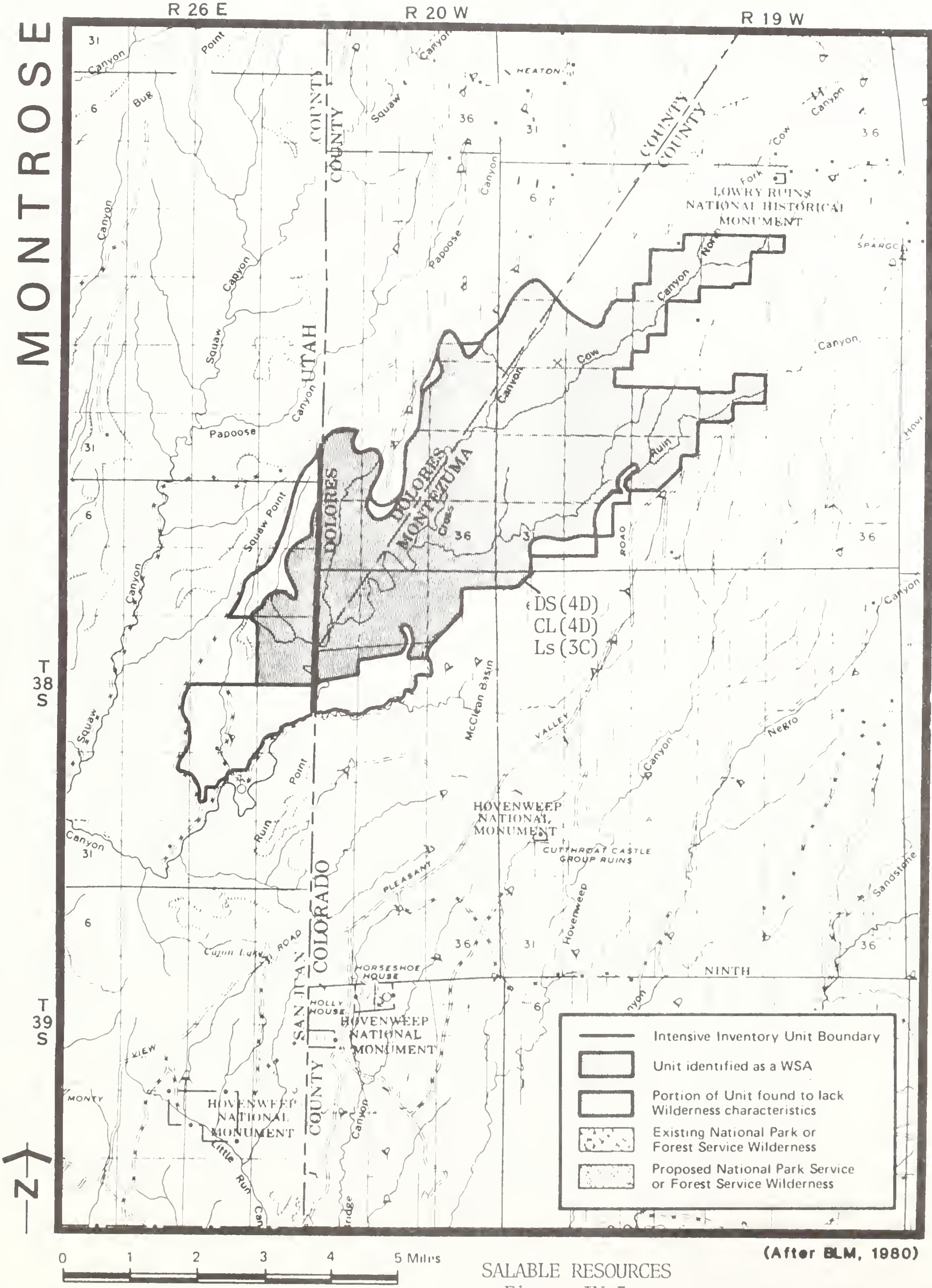
SQUAW/PAPOOSE CANYONS WSA (CO-030-265A and UT-060-227)

Resource	Classification	Comments
Dimension Stone	4D	The economic potential is rated as low to moderate. The Dakota Sandstone may contain favorable units.
Structural & Bentonitic Clays	4D	The economic potential is rated as low to moderate. The Morrison and Mancos Shale Formations may contain favorable units.
Limestone	3C	The Paradox Formation may contain favorable units. The economic potential is rated as low to moderate.

CAHONE CANYON WSA (CO-030-265D)

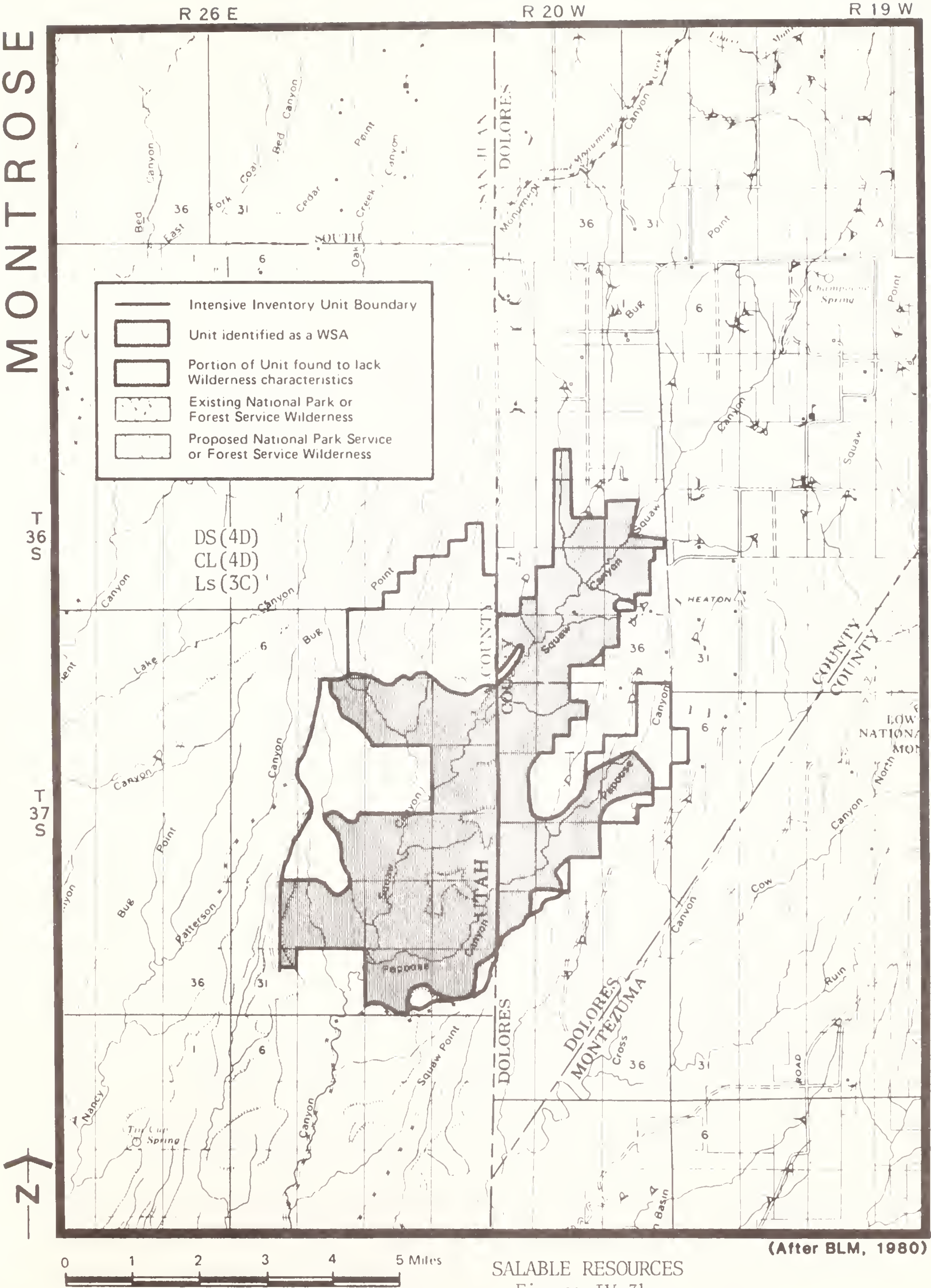
Resource	Classification	Comments
Dimension Stone	4D	The Dakota Sandstone is a favorable unit for dimension stone with a low to moderate economic potential.
Structural Clays	4D	Structural clays have been derived from the Morrison Formation. The economic potential is low to moderate.
Structural & Bentonitic Clays	3C	The Mancos Shale may be a favorable unit. The economic potential is low to moderate.
Limestone	3C	The Paradox Formation may be a favorable unit. The economic potential is low to moderate.

CO-030-265 Cross Canyon



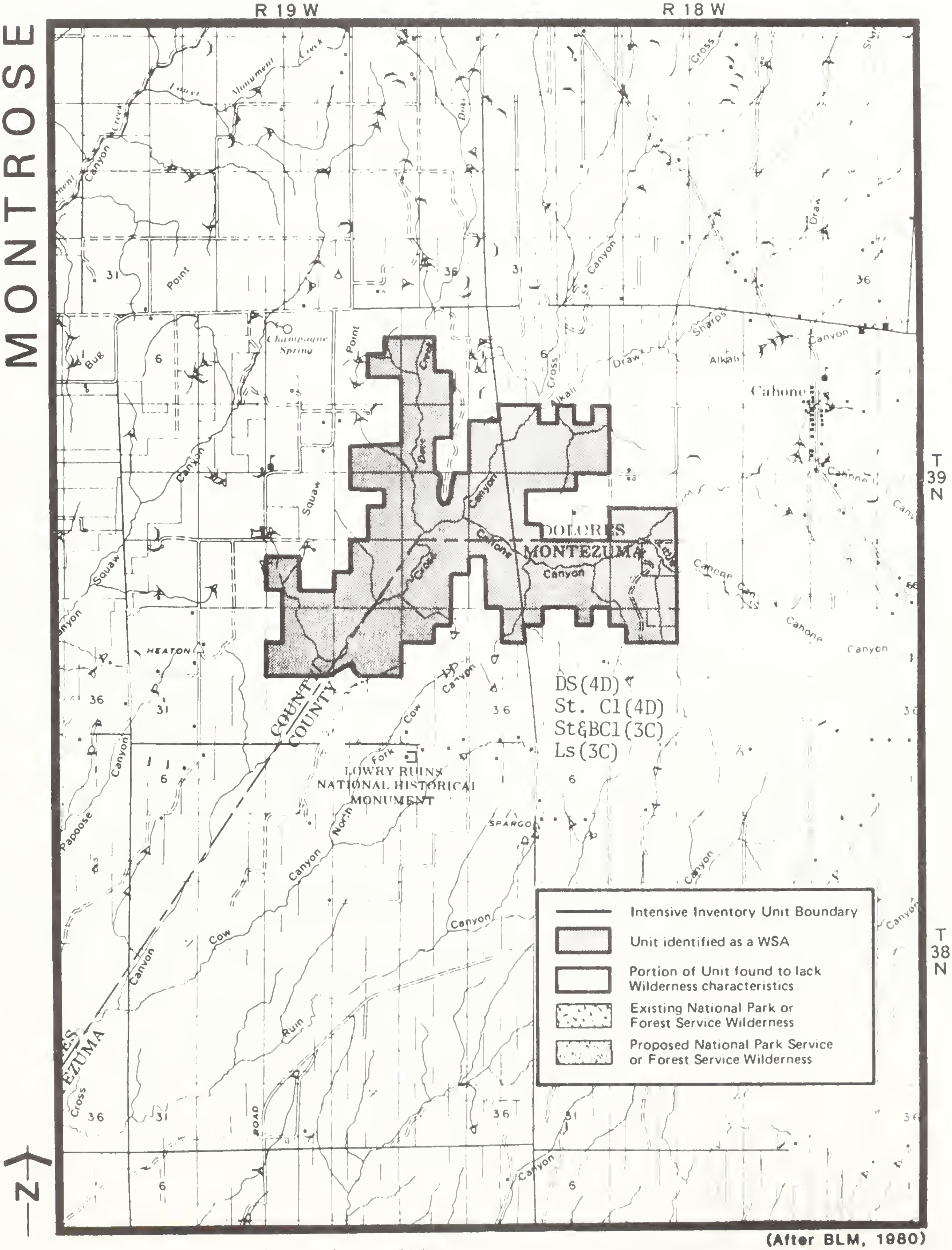
SALABLE RESOURCES
Figure IV-3a

CO-030-265A Squaw/Papoose Canyons



SALABLE RESOURCES
Figure IV-3b

CO-030-265D Cahone Canyon



SALABLE RESOURCES
Figure IV-3c

SECTION V

RECOMMENDATIONS FOR FURTHER STUDY

In the course of analyzing, assessing and evaluating each of the WSA's in the Cross Canyon - Squaw/Papoose Canyons - Cahone Canyon GRA - both in the field and in available data - certain unknowns were uncovered that should be investigated in order that each WSA's GEM resources be more fully documented. This section recommends the type of studies and data gathering that should be made to inventory more completely each WSA.

CROSS CANYON WSA (CO-030-265 & UT-060-229)

Since this area is known to have potential for oil, gas, carbon dioxide, helium, coal, and uranium-vanadium resources, it is recommended that every effort be made to ascertain the full extent of this potential. Cooperative agreements should be made with various oil and gas producers to obtain proprietary information not available to this study. Such information as the projected reserves of the area, the importance of structural zones in localizing oil, gas and carbon dioxide pools, and the exact identification of pay zones within the generally favorable lithologies is of vital importance in the exact areal delineation of subsurface potential.

In addition, a detailed program of geologic mapping and sampling should be carried out to fully delineate the extent of the coal bearing horizons in the Cretaceous Dakota section. Any sampling carried out under such a program must include analysis of the coal material for the ash and sulphur content as well as Btu content. Much work has already been done on lithofacies reconstruction in the Cretaceous in adjacent areas. Studies of this nature would be useful in determining the probable northern extent of the coal measures and thus, the viability of the coal as a minable resource.

Of particular importance should be a detailed examination of the outcropping units of the Jurassic Morrison Formation and detailed mapping of the facies units within this generally favorable formation.

Any existing mines, prospects and mineral occurrences should be mapped and sampled to delineate the full extent of existing mineralization and the potential of the host lithologies. This is of particular importance in the determination of the uranium-vanadium potential of the Jurassic Morrison Formation and the coal potential of the Cretaceous Dakota Formation. In other areas these units have significant potential GEM resources and thus, should be studied in this area where there is little available information. Though the airborne and ground (NURE-HSSR) information does not delineate any areas with anomalous values, ground radiometrics in conjunction with the geological-geochemical would be helpful in identifying any areas of mineral potential.

Examination of any outcrops of the Mancos Shale for specialty or structural clays should be made in the course of any geologic mapping program.

From the work to date and the material compiled in the course of this project, it appears that this area has significant potential for GEM resources.

SQUAW/PAPOOSE CANYONS WSA (CO-030-265A & UT-060-227)

The GEMS potential of this area is essentially the same as the nearby Cross Canyon area. This being the case, it is recommended that the same sort of geological mapping and geochemical sampling program also be done in this area. Such a program should concentrate on the favorable sections of the Jurassic lithologies and seek evidence of favorable environments for mineral deposition.

Of particular importance should be a detailed examination of the outcropping units of the Salt Wash Member of the Jurassic Morrison Formation and detailed mapping of the facies units within this generally favorable formation.

There are known prospects and mineral occurrences adjacent to the WSA, and the area is known only from reconnaissance mapping.

Any existing mines, prospects and mineral occurrences should be mapped and sampled to delineate the full extent of existing mineralization and the potential of the host lithologies. This is of particular importance in the determination of the uranium-vanadium potential of the Jurassic Morrison Formation and the coal potential of the Cretaceous Dakota Formation. In other areas these units have significant potential GEM resources and thus, should be studied in this area where there is little available information. Though the airborne and ground NURE-HSSR information does not delineate any areas with anomalous values, ground radiometrics, in conjunction with the geological-geochemical, would be helpful in identifying any areas of mineral potential.

The known coal seams in the area should be mapped in detail and sampled. Analysis for Btu, ash and sulphur content of each deposit should be made and the extent of the seam or seams delineated.

Stream sediment samples should be analyzed for their copper, molybdenum, lead, arsenic, uranium, vanadium and gold content. This data will supplement the existing NURE-HSSR information.

In conclusion, from the work to date and the material compiled in the course of this project, it appears that the potential for GEM resources in this area is largely unknown.

CAHONE CANYON WSA (CO-030-265D)

Since this area is known to have great potential for oil, gas, coal, and some potential for uranium-vanadium resources, it is recommended that every effort be made to ascertain the full extent of this potential. Cooperative agreements should be made with various oil and gas production as the projected reserves of the area, the importance of structural zones in localizing oil and gas pools, and the exact identification of pay zones within the generally favorable lithologies is of vital importance in the exact areal delineation of sub-surface potential.

In addition, a detailed program of geologic mapping and sampling should be carried out to fully delineate the extent of the coal bearing horizons in the Cretaceous Dakota Formation. Any sampling carried out under such a program must include analysis of the coal material for the ash and sulphur content as well as BTU content. Much work has already been done on lithofacies reconstruction in the Cretaceous in adjacent areas. Studies of this nature would be useful in determining the probable extent of the coal measures and thus, the viability of the coal as a minable resource.

The known coal seams in Cahone Canyon should be mapped in detail and sampled. Analysis for Btu, ash and sulphur content of each deposit should be made and the extent of the seam or seams delineated.

Stream sediment samples should be analyzed for their copper, molybdenum, lead, arsenic, uranium, vanadium and gold content. This data will supplement the existing NURE-HSSR information.

Of particular importance should be a detailed examination of nearby outcrops of the Salt Wash Member of the Jurassic Morrison Formation and detailed mapping of the facies units within this generally favorable formation. Where possible, projections should be made of the extent and mineral potential of the Salt Wash Member under the WSA. This can only be accomplished by detailed analysis of geophysical and drilling information.

In conclusion, from the work to date and the material compiled in the course of this project, it appears that the potential for GEM resources in this area is largely unknown.

SECTION VI

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